Sensor-based Learning Support

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Chapter I

General Introduction

First steps

Humans first step on earth roughly 200 000 years ago (Alemseged, Coppens, & Geraads, 2002; Stoneking & Soodyall, 1996). In contrast with most animals that come to the world with an almost fully developed brain, the human brain is underdeveloped at birth. It comes to the world with a limited amount of genetic hardwiring. While genes provide general guidelines for the human brain's neural network, world experience and learning have an enormous role in its development (Eagleman, 2015). This underdevelopment at birth results in a great vulnerability, humans must be taken care of for many years and learn from others in order to survive. On the bright side, this underdevelopment at birth results also in the possession of a brain with an enormous flexibility allowing humans to adapt and learn from the world. Learning from the world and from others has not only helped humans to survive, it has allowed humans to spread and survive in every ecosystem in the planet (Boyd, Richerson, & Henrich, 2011). In current times learning is still a vital and an essential quality of human nature.

Technology and Learning

For some 160 000 years humans learned without the support of any known technology. Humans learned through imitation (Bolton, 1923; Meltzoff & Prinz, 2002), by trial and error (Young, 2009; Starch, 1910), and with the help of other human teachers. These ancient learning practices that are still being practiced nowadays have some limitations that humans have been trying to address with the use of technology. Examples of these limitations are persistence, scalability and accessibility of learning resources. In those times teachers could be identified as the learning resources that were able to pass their experience and knowledge to younger generations. Probably the major limitation of these ancient learning practices is the persistence of the learning resources. Without the use of technology, this persistence is bound to the human memory. Human memory is not very reliable, humans have a limited lifespan, and a tendency to distort and forget facts (Schacter, 1999). If knowledge was not passed on through words of mouth, it had to be reconstructed or it would be banished forever.

Some 40 000 years ago humans came up with a technological solution to overcome the human memory limitations. They discovered a way to create abstract representations of their thoughts and print them on walls of caves (Pike, et al., 2012; Clottes, 2003; Amos, 2012). Thousands of years of storytelling and learning through word of mouth were enhanced by the persistence of printed thoughts. Some 4600 years ago with the use of papyrus (Tallet, 2012) and the development of writing systems, it became possible to document experiences and knowledge in a printed portable way without direct access to its originators. The reproduction of printed knowledge was still very time consuming and the vast majority of people could not get access to it. Nevertheless, the new mobility feature of printed knowledge provided an important change with regard to the accessibility of learning resources. A few thousands of years later, in the middle of the 15th century the printing press was discovered. This discovery allowed the mass distribution of printed knowledge contributing to the accessibility and scalability of learning resources, and the expansion of literacy in layman people (Kreis, 2004). In current times with the use of the Internet and mobile technologies it is possible to get access to virtually all information in the world almost at anytime and anywhere.

Having unlimited access to information, however, is not sufficient for learning. As Aristotle points out: “For the things we have to learn before we can do them, we learn by doing them, e.g. men become builders by building and lyre players by playing the lyre; so too we become just by doing just acts, temperate by doing temperate acts, brave by doing brave acts” (Barnes, 2004). Aristotle is not the last person who suggested that the learner has to take an active role in the learning process. This suggestion has also been supported by thinkers such as B.F. Skinner who methodically studied the effects of positive reinforcement as a feedback mechanism for learning, and J. Piaget who proposed that learners are the constructors of their knowledge (Austin, Orcutt, & Rosso, 2001). The proposition that the learner is not a mere observer but rather an active participant of the learning process unveils the complexity of this process. It reveals that besides the transmission of information, interventions such as practice and feedback have a powerful impact on the learning process (Hattie & Timperley, 2007).

Interactive Learning Technologies

In the first half of the 20th century S. L. Pressey invented the first teaching machines. These machines were able to give immediate feedback to multiple-choice tests (Pressey, 1927). Inspired by Pressey’s work, in 1956 B.F. Skinner conceptualized teaching machines able to provide feedback for subjects such as arithmetic, vocabulary and spelling. Following the behavioristic approach of providing positive reinforcement as feedback, these machines allowed the learner to proceed once their performance was correct (Skinner, 1958). In the early 1960s mechanical versions of Skinner’s conceptualized teaching machines reached the market. Technologies were now capable to provide learners with basic personalized support. One example of these learning machines is the Min-Max that sold over 100,000 copies (Benjamin, 1988). The popularity of these machines came with all sorts of criticism, some of it claiming the dehumanization of learning (Kreig, 1961; Greene, 1968), lost of teaching jobs (Broudy, 1962), and the poor quality of education provided by these machines (Wohlwill, 1962).

During the decades of the 1960s and 1970s, mechanical teaching machines became outgrown by computer-assisted instruction (CAI). One representative CAI system of these decades was the Programmed Logic for Automatic Teaching Operations (PLATO) developed at the University of Illinois. PLATO supported the creation of digital courses allowing teachers and students to communicate through the network (Pagliaro, 1983). Another exemplary CAI system from this period is LOGO which was an interactive programming language designed to support students with the development of their programming skills (Fischer & Kling, 1974). During this period research on CAI started with the exploration of means to provide educational resources to students based on their current level of knowledge (Carbonell, 1970; Barr, Beard & Atkinson, 1976; Koffman & Perry, 1976). These studies showed how technology could support learning through instructional scaffolding, and gave birth to the foundations of the adaptive systems used nowadays. Regardless of the complexity and utility of the systems developed in this period, the general access to computers was minimal and only relatively few students could benefit from them.

In the early 1980s, soon after the introduction of the first IBM personal computer, intelligent tutoring systems (ITS) started to appear. One example of an early ITS, is the classic LISP tutor, which is able to provide feedback to learners of the LISP programming language (Farrell, Anderson, & Reiser, 1984). In contrast with the teaching machines and systems developed in the past decades, the newly developed ITS were able to go beyond supporting learners through a behavioristic approach. ITS were able to make intelligent decisions on how to support the learner based on knowledge of the domain, the learner, instructions and/or commonly occurring errors (Buchanan, 2006). The interaction with desktop computers available at the time presented some limitations to the ITS. Learners were restricted to interact with ITS through direct input, using the available input devices at the time (in most cases mouse and keyboard). Therefore, learning interactions were rather obtrusive, and learning applications that ITS could support were limited to the things that one can do and learn while sitting down before a desktop.

In the following years computers became more powerful and accessible. In the middle of the 1990s with the boom of the Internet computers became a popular tool for communication. Universities all over the world introduced stepwise Learning Management Systems (LMS), bringing support to millions of students.

The evolution of computers continued. Computers became more powerful, smaller, energy efficient, mobile, user friendly and popular. In 2007, 122 million smartphones with computing capabilities were sold world wide, and these numbers have continuously risen since then [1]. Educational technologies embraced the advances of these mobile technologies and the concept of Mobile Learning started to spread. Mobile Learning applications allow learners to perform learning tasks outside of a classroom. This allows learners to receive contextualized instruction based on variables such as time and location. Moreover, learners can use the features of their mobile devices to collect data for their assignments (Ternier, Klemke, Kalz, Van Ulzen, & Specht 2012).

Currently, not only phones are being enhanced with computational features. With the use of sensors, everyday objects which previously seemed to be unanimated, are turning into smart devices with the capability to sense the environment, integrate and present digital information and services for nearly every situation and context (Börner, Kalz, & Specht, 2013). A sensor is a device which detects or measures a physical property and records, indicates or otherwise responds to it (Oxford Dictionaries, 2017). Sensors are able to retrieve information about persons, their environment, and interactions among persons and their environment (Van Est, Rerimassie, Van Keulen &

[1]https://www.statista.com/

Dorren, 2014). With the use of sensors it should become possible to automatically detect and measure the activities performed by learners, and on a second step use this sensor data to support the learning process.

Supporting the learning process through the use of sensors presents some technical and educational challenges. The technical challenges deal with investigating how to use sensors and their data in order to infer and present useful information to the learner. Which sensors should be used? What type of data do the sensors provide? Is it possible to make inferences out of the sensor data?

The educational challenges deal with identifying the relevant learning features to be tracked, how to assess them correctly and how to present this assessment in ways that have a positive effect on learning. Which inferences can support the learning process? What kind of support can be provided by these inferences? How should these inferences be presented to humans in order to support learning?

Can sensors become a driving factor in the evolution of interactive learning technologies? This dissertation aims to tackle technical and educational challenges exploring how sensors, as technologies that are becoming pervasive in our civilization, can be used to support learning, an essential quality of the human nature.

Context of the Research

The research presented in this dissertation was partially funded by the Metalogue project [2]. The main goals of this project were to design a dialogue system with metacognitive capabilities that is based on natural spoken language and multimodal interaction and to evaluate the developed technologies in an educational setting.

The research conducted for this dissertation fits into the project by investigating how the multimodal data collected by sensors can be used to support the development of nonverbal communication skills for public speaking.

Outline of the research

The research conducted for this dissertation consists of three different sections. It started with a literature study, and continued following a design-based research approach (Anderson & Shattuck, 2012) that comprised three iterations.

Literature Study

Chapter II presents a systematic literature review of the state-of-the-art of sensors-based platforms based on their learning support. The sensor-based platforms were examined according to their potential contribution to the cognitive, affective and psychomotor domain of learning (Bloom, Englehart, Furst, Hill & Krathwohl, 1956). The

[2] http://www.metalogue.eu/

review explores their possible contribution to formative assessment, and analyses how they provide feedback to learners. The main findings from this analysis showed that sensor-based platforms have been used to support a vast number of applications with potential support for learning. However, the learning effects of these sensor-based platforms have hardly been studied. Additionally, the feedback provided by these platforms is limited to the emission of a particular auditory, visual or haptic signal whenever the user's performance is outside of the established parameters. Overall, while sensors can give an abundant amount of information to their users, the main challenge is to select and present this inferred information in such a way that it becomes feedback or information that learners can assimilate effectively.

First Iteration

Steered by the main findings of the literature study, the research of this dissertation continued following a design-based research approach, which consists of an iterative process where sensor-based prototypes would be designed and tested in order to proceed to the following iteration of the research. Constrained by the context of the Metalogue project, which investigated multimodal dialogue systems, the development of public speaking skills was the scenario chosen for the studied prototypes. Public speaking is a simplification of a dialogue were multimodal aspects such as the nonverbal communication of the speaker are very important.

Chapter III describes a formative study on the Presentation Trainer (PT), a sensor-based prototype designed to support the development of nonverbal communication skills for public speaking. This study describes the first two versions of the PT and the results from their corresponding user tests. The results of these tests provide with practical guidelines on how to design immediate feedback interfaces that support the development of complex skills such as public speaking.

Chapter IV portrays a quasi-experimental study of the third version of the PT. This third version of the PT was built according to the guidelines provided by the previous prototypes. The results showed that the feedback of the PT helped learners to improved self-awareness, self-confidence and performance according to machine-based measurements.

Second Iteration

This second iteration addresses the limitations of the first one. The first iteration shows how to construct a prototype able to provide feedback to learners in an effective manner, thus helping them to improve their performance according to machine-based measurements. Obviously, instead of machines, human audiences are the actual receivers of a public speech or presentation. Giving a flawless presentation according to a machine-based score does not mean much if the presentation does not appeal to humans. A crucial point to address in this second iteration was to explore whether training with the PT leads to better presentations according to humans and therefore supports learners in becoming better public speakers. Chapter V and Chapter VI of this dissertation aim to address this point.

Chapter V describes an expert study. This study consists of interviews with experts in public speaking. These interviews allowed the identification of behaviors that affect the quality of presentations, together with the identification of limitations and improvements of the PT.

Chapter VI studies whether practicing with the PT can actually help learners to give better presentations according to human audiences. Participants in the study had to deliver an elevator pitch to an audience two times: the first time without having any special practice, and the second time after practicing with the PT. The audience assessed both pitches. Results from the study show that the pitches given after the practice sessions with the PT received better scores.

Third Iteration

The third iteration continues with the improvement of sensor-based applications for the development of public speaking skills by addressing pending gaps from the previous iterations and literature review. It also ties findings from the previous studies together and starts with the exploration on how, in the future, educational institutions can successful adopt sensor-based applications for public speaking.

One key finding from Chapter V is that ultimately there is no right way to do a presentation, therefore providing the learner only with corrective feedback, as the PT does, might not always be desirable. Experts, interviewed in Chapter V, commented on how a tool such as the PT could be improved by helping learners to reflect about their performance. Chapter VII presents a formative study on a self-reflection module for the PT, which was built based on the findings of the expert study. Testing the self-reflection module revealed some interesting findings: some participants expressed their need to rewrite the script of their presentation based on the information revealed by the self-reflection module. Results also revealed that the use of the self-reflection module does not necessarily translate into better performance according to machine-based measurements.

Results from the literature review in Chapter II indicated that support given by sensor applications to the affective domain of learning was underdeveloped when compared to the support given to the cognitive domain. Since speaking to the public is considered an event that causes anxiety (Hofmann, Gerlach, Wender & Roth, 1997), and anxiety can undermine performance (Derakshan, & Eysenck, 2009), it was decided to explore this further. Chapter VIII tackles this problem and presents a study on *the Booth*. *The Booth* is a sensor-based prototype designed to elicit a resourceful emotional state in learners. Main findings from this study showed that the use of *the Booth* resulted in a reduction of negative emotions such as anxiety, stress, etc. and an increment in positive emotions such as happiness, confidence and joy.

Chapter IX builds on the findings from all previous studies, and explores the use of the PT and *the Booth* in a real world scenario. The chapter reports on a study conducted in a secondary school where first year students following a course in oral communication tested the tools. Results from this study point out the current limitations and educational opportunities of these two tools, with the purpose to mitigate the risks for the successfully adoption of these type of sensor-based applications by educational institutions in the future.

General discussion

Finally, Chapter X reviews the general findings of the dissertation, addresses its limitations. By taking into account the findings and limitations previously reviewed, the chapter then suggests paths for future research and discusses how some of the findings of the conducted research can be generalized for different types of sensor-based learning applications. The chapter concludes with the author expressing his personal vision regarding the purpose of education taking in consideration current advances in technology.

Part I

Literature Study

Chapter II

Augmenting the Senses: A Review on Sensor-Based Learning Support

This first part of the dissertation explores the state-of-the-art of sensor-based learning support. This chapter presents a systematic literature review that analyzed 82 sensor-based prototypes exploring their learning support. To study this learning support the prototypes were first classified according to the Bloom's taxonomy of learning domains. The analysis continues by exploring how the analyzed prototypes could be used to assist on the implementation of formative assessment, paying special attention to their use as feedback tools. The analysis leads to the identification of current gaps in the field and suggests paths for future research.

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Introduction

The digital and physical worlds are currently merging, opening new possibilities for us to interact with our environment, as well as for our environment to interact with us. This development is mainly driven by two technologies: display technologies and sensor technologies. Display technologies in the sense of personal mobile displays, as also a variety of embedded public displays, enable the integration and presentation of digital information and services in nearly every situation and context (Börner, Kalz & Specht, 2013). Sensor technologies enable the development of real-time information systems and the extension of classical objects to be enhanced and integrated into digital ecosystems. Everyday objects, which previously did not seem aware of the environment at all, are turning into smart devices with sensing and tracking capabilities. Cisco estimates that by 2020 there will be 50 billion devices connected to the Internet (Evans, 2011) and one of the main drivers for this to happen is the increasing number of low-cost sensors available (Swan, 2012).

A sensor is commonly defined as: "a device that detects or measures a physical property and records, indicates, or otherwise responds to it." (Oxford Dictionaries, 2014). The mere linguistic definition of a sensor seems restrictive, in the sense that specific computer programs have been used as sensors, by tracking recent songs played, current URLs open, log of incoming calls and some other non-physical properties (Miluzzo, Lane, Eisenman, & Campbell, 2007). Consequently, the definition of a sensor being used in this review is: "a physical or virtual object used for tracking, recording or measuring." An overview of the identified sensors together with their measured properties and identified usages is shown in Appendix A. Coupling sensors with software components creates new types of tools with the capability to measure, analyze and (immediately) present results of the obtained data. The name for these instruments has not been standardized yet, and in previous works they have been referred as smart-sensors (Hunter, Stetter, Hesketh, & Liu, 2010) sensor systems (Guo, Wu, Tsinalis, O., Silva, & Gann, 2012), sensor platforms (Tørresen, Hafting & Nymoen, 2013), ecosystems (Swan, 2012), etc. In the remainder of this article these tools will be denoted as sensor-based platforms.

The ability of sensor-based platforms to act according to their retrieved and analyzed data suggests a possible use of them as learning tools. In order to get an overview of the state-of-the-art of sensor-based learning support and to find directions for further research on it, in this literature review we analyzed the learning support of sensor-based platforms that were designed for educational purposes as well as sensor-based platforms that were designed for other purposes but that are also able to support learning through the presentation of relevant information for performance support, analysis and contextual awareness. With the purpose to get an overview of the different areas of learning that have already been influenced by sensor-based platforms, we started our study analyzing the connections between the different types of sensor-based platforms and their support for the commonly distinguished learning domains: the cognitive, psychomotor and affective domain (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956). Since one of the current educational challenges is the implementation of formative assessment (Russell, 2008), within the learning domains we in particularly focused on exploring whether sensor-based platforms can assist on its implementation. Formative assessment provides learners with information that allows them to improve their performance and learning. In our study we carefully analyzed how sensor-based platforms have been used as feedback tools, since formative assessment includes high quality feedback, which should be given as soon as possible after submission; be relevant to the task and the pre-defined assessment criteria; and should help the student to understand how to improve her work (not just highlighting strengths and weaknesses) (Gedye, 2010). However, the required effort for this type of assessment easily leads to a work overload for teachers forcing them to give merely summative instead of formative feedback (Berlanga, Van Rosmalen, Boshuizen, & Sloep, 2012). Implementing formative assessment with more human work force is currently not a feasible solution, therefore in this review we explored whether sensor-based platforms can contribute to it.

To summarize, this article gives an overview on how sensor-based platforms have been used for learning support, by exploring their contribution on the different learning domains, the implementation of formative assessment, and their status as feedback tools. The remainder of this article is organized as follows: Section 2 presents the classification framework used to analyze the prototypes described in the articles. Section 3 gives an outline of the used methodology. Section 4 presents the results of the analysis. Finally, Section 5 discusses the results and presents an outline for further research on the topic.

Classification Framework

With the purpose of identifying the already existing best practices for the use of sensors in learning as well as identifying directions for the further development on the state-of-the-art of sensor-based learning support, in this review we examined and studied the current link between learning support and the state-of-the-art of sensor-based platforms prototypes found in literature. In order to conduct our research we proposed a classification framework examining:

- Learning domains: get an overview of sensors and learning.
- Formative assessment: focus our research in sensors and learning, exploring how they can assist with a main current educational challenge.
- Feedback: deepening our research in sensors and learning studying how they have been used for giving feedback, which is a key element for formative assessment and one of the most important interventions in learning.

To get an overview of the type of learning support that has already been tinted by sensor applications, we first analyzed and classified the existing sensor-based platforms according to the support that they give in the commonly identified learning domains (Bloom et al., 1956). This classification seems suitable because to our knowledge it covers all aspects of learning, allowing us to get an impression of the development of sensor-based learning support, highlighting the areas of learning that have been already influenced by sensors.

The unobtrusive capabilities of sensor-based platforms to measure and analyze data lead us to think of their possible support for assessment. Therefore we deepen our analysis exploring how the state-of-the-art of sensor-based platforms can assist in the implementation of formative assessment, which is a current educational challenge. To study this contribution we analyzed how the state-of-the-art of sensor-based platforms can be used to assist in the 9 aspects of formative assessment that have been identified in (Sadler, 1998; Bennett, 2011). Feedback is a key aspect of formative assessment and one of the most important influences in learning (Hattie & Timperley, 2007), hence to gain insight in the effectiveness of sensor-based platforms as feedback tools, we studied their feedback based on the framework of effective feedback Hattie & Timperley, 2007).

Classification Framework for Learning Domains

Currently most well known sensor applications on the market, such as the Polar heart rate monitors (Polar, 2014), Nike+ (Nike+, 2014), Digifit (Digfit, 2014), or Xbox fitness (Xbox Fitness, 2014) are used in the field of sports. They are designed to track and give feedback about the physical performance of the users, helping them in training their motoric skills. With the intention to explore whether the use of sensor data can go beyond that, we explored in scientific literature the areas where learning support have been given by sensor-based platforms. For that we analyzed the prototypes described in literature according to their support given on the commonly identified learning domains. These domains are: the cognitive, affective and psychomotor domain (Bloom et al., 1956) (see Figure 2.1). The cognitive domain refers to knowledge and the development of intellectual skills. It includes the recall or recognition of facts, and the development of intellectual abilities and skills (Bloom et al., 1956). This learning domain contains two dimensions: the knowledge dimension and the cognitive process dimension. The knowledge dimension refers to the type of knowledge that can be acquired and consists of four categories: factual, conceptual, procedural and metacognitive knowledge. The cognitive process dimension deals with how the knowledge is used. It contains six categories ranging from remembering facts to the creation of new concepts and objects using the acquired knowledge (Krathwohl, 2002). In order to get an understanding on how sensors can support the cognitive domain of learning, we explored the practices that have been used by sensor-based platforms to support these two dimensions.

The affective domain refers to the approach in which learners deal emotionally with things, such as values, feelings, motivations and attitudes. This domain is usually categorized according to the complexity of the behavior incorporated by the learner. Starting from being open to receive the phenomena to internalize these phenomena until they become a characteristic feature of the learner (Krathwohl, Bloom, & Masia, 1973). In this review we explored how the identified prototypes have been used to affectively support learning, enabling us to extract and analyze the strategies used by sensor-based platforms to present support on the affective domain.

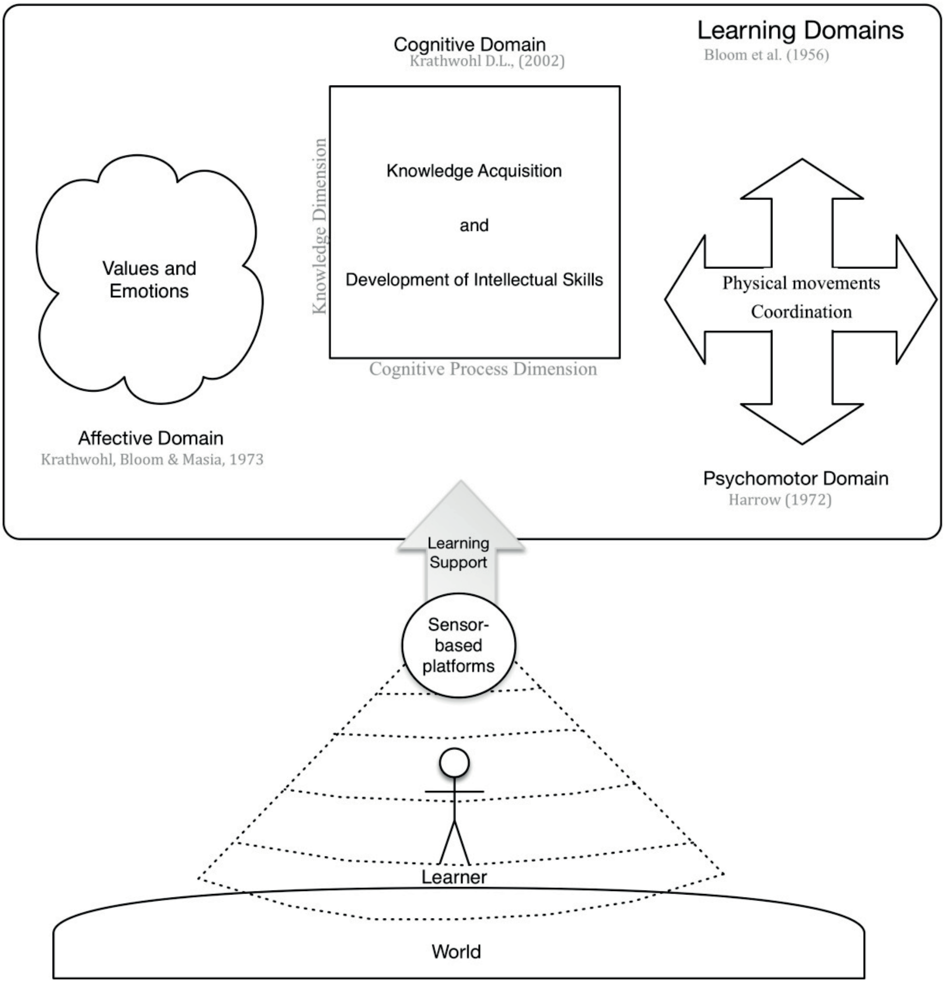

Figure 2.1 Sensor-based learning support on the learning domains.

The psychomotor domain deals with physical movement, coordination and the use of the motor-skill areas. The development of these skills requires practice and it is evaluated in terms of precision, distance, speed or techniques in execution. Six categories have been identified for this domain: reflex movements, fundamental movements, perceptual, physical activities, skill movements, and non-discursive communication (Harrow, 1972). To explore the current sensor-based learning support on the psychomotor domain of learning, we investigated which of these categories have already been supported by sensor-based platforms and analyzed how this support has been achieved.

Classification Framework for Formative Assessment Support

Once having an overview of the possible use of sensors in learning we wanted to explore whether they can be used to help solving a current challenge in education and learning. As introduced above, sensor-based platforms can unobtrusively measure and analyze data, thus suggesting their use in assessment tasks. Therefore, in this second dimension of our classification framework we have classified the analyzed prototypes according to their functions for formative assessment, investigating in which ways sensor-based platforms can contribute to its implementation. From a broad perspective formative assessment refers to the assessment that provides the learner with information, which allows them to enhance their learning and performance (Gedye, 2010). By examining the qualities that allow highly competent tutors to contribute to formative assessment (Sadler, 1998), and the strategies discussed on the "Keeping Learning on Track® Program" (Bennett, 2011), we have identified nine aspects that contribute to formative assessment (see Figure 2.2):

- Knowledge of subject matter, allows analyzing the performance of the learner, identifying the origin of its errors.
- Knowledge of criteria and standards, allows giving learners tasks according to their current level.
- Attitudes toward teaching, deals with the empathy from the tutor towards the students and the desire to help students in their development.
- Skills in setting, referring to the capacity of setting assessments that reveal understanding and skills and testing the desired outcomes.
- Evaluative skills, allowing to make appropriate judgments and to deal with the possible responses of the learners.
- Sharing learning expectations, identifying the learners' expectations and allowing sharing them across the peers.
- Self-Assessment, allowing to structure opportunities to take responsibility of own learning.
- Peer-Assessment, allowing to structure opportunities for activating learners instructional resources for each other.
- Feedback, referring to the evaluative information on the positive and negative features of the student's work.

In this dimension of the classification framework we investigated how the sensor-based prototypes described in literature support these aspects of formative assessment. The analysis of feedback, an essential aspect of assessment, will be done separately and discussed in the next section.

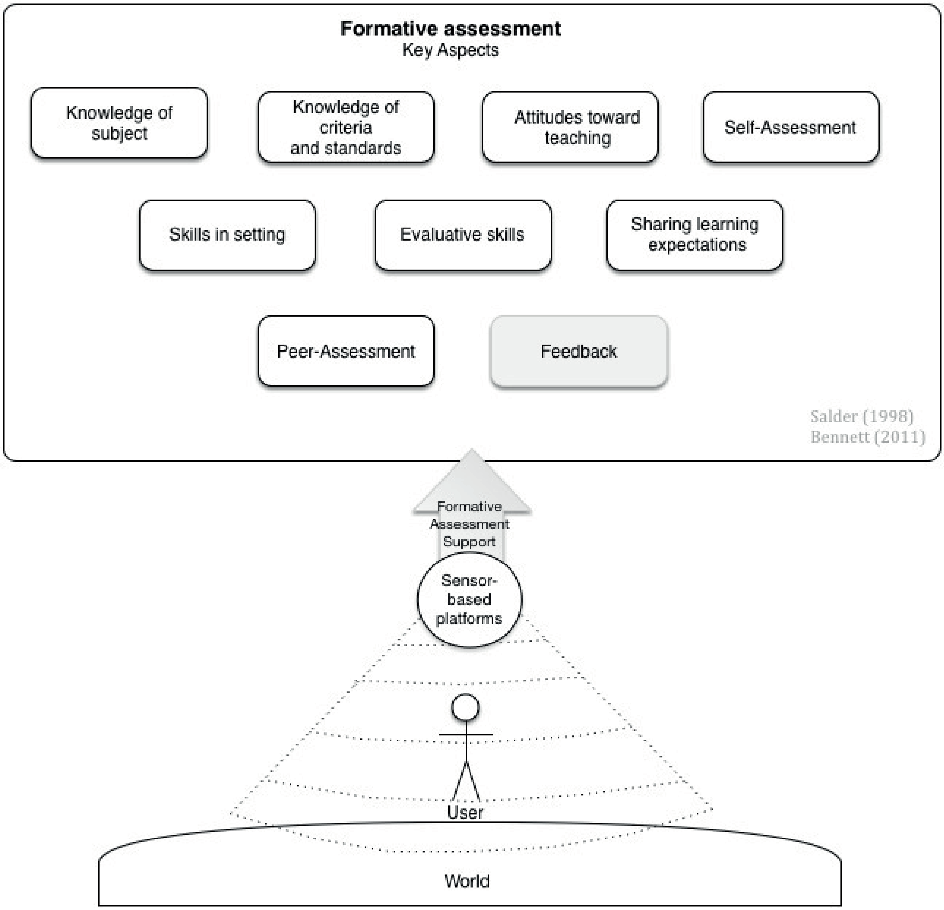

Figure 2.2 Sensor-based support on formative assessment.

Classification Framework for Feedback

Feedback is one of the most powerful interventions in learning (Hattie & Timperley, 2007), and one of the most beneficial thing tutors can do to students is to provide them with feedback that allows them to improve their learning (Nicol & Macfarlane-Dick, 2006). High quality feedback is a key element of formative assessment (Gedye, 2010). Therefore, we decided to analyze the type of feedback given by the studied prototypes. Feedback in this study is defined as the information about a person's behavior or performance of a task, which is used as a basis for improvement (Oxford Dictionaries, 2014). The effective feedback framework in (Hattie & Timperley, 2007) focuses on how feedback can be used to positively influence the learning process. Consequently, we analyzed the alignment between the feedback of the studied prototypes and this framework.

Effective feedback gives answers to the following questions: “where am I going?”, “how am I going?” and “where to next?” (see Figure 2.3) (Hattie & Timperley, 2007). The question “where am I going?” refers to the learner’s goals; goals produce persistence at task performance while facing obstacles, and support the resumption of disrupted tasks in the presence of more attractive alternatives (Bargh, Gollwitzer, Lee-Chai, Barndollar, & Trötschel, 2001). The answer to “how am I going?” provides information relative to a task or performance goal of the user. Finally, the answer to “where to next?” shows the learner the next steps to take towards the completion of her goal. Implementing the answers to these questions on a computerized system is not a straightforward task. In order to answer the question of “where am I going?” first it is important to know the goals of the user. The challenge comes in reminding the user about these goals and presenting the user with feedback on how the current task and performance aligns to the goals. Work regarding feedback loops has suggested that by presenting the user with evidence of his current behavior together with the consequences allows the user to perceive an alignment between his performance and goals (Goetz, 2011). Sensors can be used as tools to collect this evidence. Presenting this evidence and the potential consequences is something that can be implemented on a sensor-based platform.

In order to answer “how am I going?”, the performance of the user needs to be tracked, and this performance has to be compared with some rules. The proposed way to classify the type of feedback that gives answer to this second question of is through the five different levels of the complexity of feedback dimension (Mory, 2004), which are:

- No feedback: no indication provided about the performance of the learner.
- Simple verification: indication of correct or incorrect performance of the learner.
- Correct response: indicates the learner how the correct performance should be.
- Elaborated feedback: indicates why the performance of the learner is correct or incorrect.
- Try again feedback: informs the learner when the performance is incorrect and allows her to attempt to change it.

The implementation to the answer of “where to next?” has two basic requirements. First, a map with all steps to achieve the learner’s goal is required. Second, it is important to identify the current position of the learner on this map. The measuring and analysis qualities of sensor-based platforms seem suitable to identify the current position of the learner on the learning map. Moreover, sensor-based platforms that make use of system adaptation techniques such as direct guidance, content-based filtering (Brusilovsky, 2004), and self-adaptation through feedback loops (Brun et al., 2009), open the possibility for them to present the learner with a personalized learning map.

In this review, we analyzed how these three questions of effective feedback have been answered by the studied prototypes. To identify the answer to the first question: “where am I going?”, we examined whether the technique described of presenting the evidence together with its consequence (Goetz, 2011) has been used by the prototypes, and explored whether some other techniques have been used to address this answer.

For "how am I going?", we analyzed how the feedback given by the prototypes relates to the feedback complexity levels (Mory, 2004). Together with this dimension, we also explored the feedback channel used by the prototypes. This channel can usually be visual, audio or haptic. The reason for this exploration is to investigate whether empirical evidence exists backing up these feedback practices.

For "where to next?" we explored how the prototypes have implemented an answer to this question, presenting attention to the inclusion of system adaptation techniques for personalized answers.

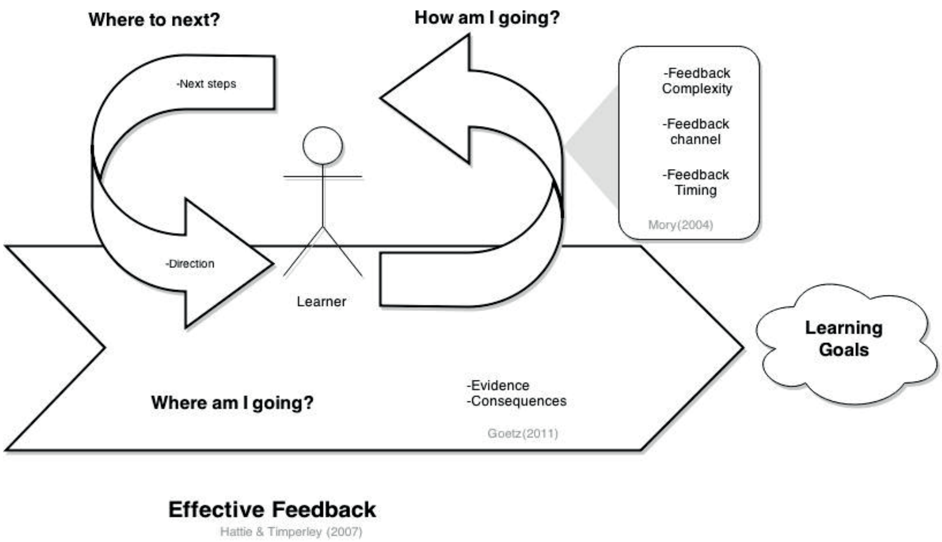

Figure 2.3 Framework used for the analysis of sensor-based support on effective feedback.

Method

The purpose of this study is to get an overview on the state-of-the-art of sensor-based learning support and to explore how the existing sensor-based platforms could bring assistance to the solution of an educational challenge, which is the implementation of formative assessment. Therefore we collected articles describing studies about sensor-based prototypes and analyzed them according to our classification framework in order to identify their learning support.

The underlying search for articles was conducted using the online repositories of: Education Resources Information Center Digital Library (ERIC), ScienceDirect (Elsevier), IEEE Computer Society, Association for Computer Machinery and the publisher Springer. The first repository ERIC was selected for being considered the largest repository in education. Elsevier was selected because it contains journals that publish research that merges the technical and educational aspects. The three other repositories were selected for containing the largest digital libraries in computing and engineering.

The search for articles was executed in different phases. The first phase was in the context of an internal study, for which we performed an initial search in early 2013 using the keywords "sensor", "application" and "learning". We examined the abstract of these papers looking for computerized applications that have been enhanced by the use of sensors, paying special attention to the ones describing applications that were designed for human learning. This first search left us with 111 articles that were considered relevant for further study.

With the purpose to include the latest research in our repository and to start a formal research on the state-of-the-art of sensor-based learning support, a second search was done in January 2014 using the keywords "sensors", "software", "applications" and "learning", while searching for articles published from 2012 to 2013. The term "software" was added to the query to restrict our search, and to exclude research focused on the hardware of sensors and not on sensor applications. After a scan through the abstracts, looking for applications where sensors have been used for human learning support, 24 articles were selected for a deeper study. While studying the literature we decided to explore more cases where systems have used sensors to adapt their behavior in order to support learners, therefore a later search was performed in March 2014 using the keywords "sensor", "adaptive", "system adaptation" and "education" for articles published after 2012. An examination of the abstracts of these search results let us with three articles that have been included in this study.

Finally in order to be sure to include some missing relevant work the state-of-the-art on sensor-based learning support; we included eight more articles and three commercial products to this review that have been pointed out by experts in the field of Technology Enhanced Learning and Human Computer Interaction as representative work in the field of tutoring, feedback and sensor systems.

To select the studies that were included in our analysis, we followed the criteria of including only articles describing sensor-based prototypes, and of which the description of these prototypes presented some information on how they can proportionate some learning support to their users. From the 146 reviewed articles and three commercial products, we were able to identify 112 different sensor-based platforms prototypes. When analyzing articles describing these prototypes, we could identify that only 82 of them include a description of the communication channel between the prototypes and the user. Since this link between the prototype and the user, is the element in a sensor-based prototype responsible to support learning, we decided to only include these 82 prototypes for further analysis.

We conducted the analysis of the prototypes in three stages. On the first stage we explored the learning support given by the prototypes. This support was classified according to the Bloom's taxonomy of learning domains (Bloom et al., 1956). On the second stage we analyzed the contribution of the prototypes in key identified aspects of formative assessment. Finally, on the third stage we took a close examination on which of the prototypes did give feedback to the user and how this feedback compared to the effective feedback framework (Hattie & Timperley, 2007).

Results

Out of the 82 analyzed prototypes that were selected for further analysis, 51 of them were created inside of an educational context specifically designed to support learning; nevertheless by analyzing the description of their communication channel and reports of their usage we identified a total of 79 prototypes providing users with relevant information for evaluation and analysis, performance support or contextual awareness, hence providing users with learning support. We recognized 79 prototypes supporting learning on the learning domains, 51 prototypes contributing to at least one key identified aspect of formative assessment and 35 prototypes giving feedback to the learner. An overview of these prototypes is found in Appendix B.

Classification for Learning Domains

With the intention to get an overview of the learning support that has already been given by sensor applications, we classified the analyzed prototypes according to their support in the different learning domains. Out of the list of 82 prototypes we identified 79 prototypes presenting learning support. By examining the output given by the prototypes, we identified that 56 of them present the user with information that can help her to remember facts, understand concepts, analyze situations, *etc.* Therefore, we classified them as prototypes supporting the cognitive domain of learning. Six of them present information with the purpose to engage users in specific activities, thus we classified them as presenting support to the affective domain of learning. Following this criterion we identified two prototypes supporting both the cognitive and affective domain of learning. The output of 17 of the prototypes presents the learner with information that aims to help her with the improvement of specific movements or her physical abilities. Hence we classified these prototypes as giving support on the psychomotor domain of learning. By analyzing the 56 prototypes that we classified as giving support to the cognitive domain of learning, we could identify three different strategies (see Table 2.1) that have been used by sensor-based platforms to give this support.

Table 2.1 Strategies supporting learning in the cognitive domain.

Sensor Usage (Design)	Number of Prototypes	Example of Sensors Used	Cognitive Domain Category
Contextual information acquisition for filtering	22	NFC, RFID, GPS, Microphones	Depends on the information attached to the context
Learner's feature identification and user modeling	11	EEG, Software sensors, NFC, Cameras, Heart-rate monitor	Depends on the information attached to the feature
Sensor Data for contextual reflection and change notification	23	Accelerometers, Air pollutants sensors Cameras, ECG, EEG, gyroscopes, microphones	Depends on the use of the information by the learner

The *first strategy* identified uses sensors to infer the *learner context*, in order to present the learner with relevant contextual information. We identified 22 prototypes following this strategy. The learner's context is commonly inferred by detecting specific objects that are situated in her surroundings. The most common technology that has been used to identify these objects is by attaching Near Field Communication (NFC) or Radio Frequency identification (RFID) tags to them. The sensors of the prototypes are able to read these tags and to present the learner with relevant contextual information. The information presented by the prototypes determines the category of the cognitive domain (Krathwohl, 2002) that receives the learning support. For example, the prototype in (Kaasinen et al., 2010) presents support on remembering factual knowledge. For this prototype NFC tags have been attached to everyday objects. When the prototype senses one of these tags, information about the tagged object is shown to the learner, this information helps her to remember specific facts about it. The prototype in (Edge, Searle, Chiu, Zhao, & Landay, 2011) uses the same strategy. Nevertheless, this prototype supports the category of applying factual knowledge. The purpose of the prototype is to help learners to learn Mandarin, for that it uses GPS sensors to identify the context of the learner and presents him with Mandarin phrases that are suitable to be applied in this context.

The *second strategy* identified on 11 of the prototypes, is similar to the first one; nonetheless this strategy instead of using sensors to track the learner's contexts, it uses sensors to track *specific features* of the learner such as the learning style (Dung, & Florea, 2012), competences based on the score of predefined pre-tests (Hsu, & Ho, 2012), attention (Linden, Habib, & Radojevic, 1996; Szafir, & Mutlu, 2013; Börner, Kalz, & Specht, 2014), emotional state (Arroyo, Cooper, Burleson, Woolf, Muldner, & Christopherson, 2009; Littlewort, Bartlett, Salamanca, & Reilly, 2011), uncertainty while using a tutoring system (Jraidi, & Frasson, 2013; Whitehill, Bartlett, & Movellan, 2008), trouble solving problems (Anderson, &. Reiser, 1985) or driving style (Serbedzija, & Fairclough, 2012). The information presented to the learner by these prototypes depends on the tracked values for these features.

The *third strategy* identified uses sensors to gather *relevant data* and presents this data to the learner. We identified 23 of the prototypes following this strategy. For example the prototype of NoiseSpy (Kanjo, Bacon, Roberts, & Landshoff, 2009) uses the microphone and GPS of mobile devices to retrieve the amount of noise in different places of a city. These different noise measurements are presented in a map allowing town planners to learn about the noise distribution patterns of a city. In this case the use that the learner gives to this information establishes the cognitive domain category supported by the prototype. This strategy is the only one identified being used by commercial products (Globisens, 2015; Vernier Software & Technology, 2015; PASCO, 2015). These products provide different visualizations of sensor data, which could help learners to analyze different phenomena from natural sciences. The application domain for prototypes using this technique of showing sensor data to support the cognitive domain of learning is broad. It can go from the field of civil engineering as in (Amaratunga, & Sudarshan, 2002), to the field of sports where due to the advances in wearable sensors, human movements are being studied in new and more precise manners

(James, Davey, & Rice, 2004; Ghasemzadeh, Loseu, & Jafari, 2009; Spelmezan, Schanowski, & Borchers, 2009). Another common application where sensor data supports learning in the cognitive domain is by monitoring the activity, behavior and state of patients in order to gain insight about their health (Greene et al., 2010; Hester et al., 2006; Hicks et al., 2010; Lee, & Carlisle, 2011; Pentland, 2004). These prototypes have been classified as supporting the cognitive domain of learning instead of the psychomotor domain, because the users of these prototypes who are able to make direct use of the sensor data are experts. By analyzing the data these experts can later use their gained knowledge to give proper advice to patients. This proper advice might indeed support them in the psychomotor learning domain, but it comes from the expert and not from the prototype. The prototype shown in (Hester et al., 2006) is an example of this; this prototype shows how wearable sensors have been used to monitor the movements of people following a heart stroke helping doctors to select the best therapy for them.

The affective domain of learning deals with attitudes, motivations, values, *etc.* We identified that the information presented to the learner in eight prototypes had the purpose to support them in this domain The analysis of these eight prototypes let us recognize three different strategies that have been used to achieve this support (see Table 2.2).

Table 2.2 Strategies supporting learning in the affective domain.

Strategy	Number of Prototypes	Example of Sensors Used
Behavior overview and review	4	Accelerometers, Barometer, Camera, Compass, GPS, Humistor, Microphone Software sensors, Thermometer
Social network visualization	2	Blood glucose meter, Software sensors
Involving learners in data collection	2	Accelerometers, Camera, Microphone, Thermometers

The *strategy of behavior overview and review* uses sensors to track certain aspects of the learner's behavior and presents the learner with the overview of it. By doing so, the learner becomes aware of how she is approaching towards the desired goal, motivating her to change or keep up with his current behavior. This strategy has been used by four of the prototypes. The prototype described in (Consolvo et al., 2008) exemplifies this strategy. The purpose of this prototype is to engage users into a more active lifestyle, for that, this prototype uses sensors to track the physical activities performed by the user, and displays the overview of them on their mobile devices. Watching the presented activity overview motivates the user to engage into a more active lifestyle.

The *strategy of social network visualization* has been used by two of the prototypes; this strategy lets learners compare themselves with peers of their network, motivating them to perform well in their learning activities. An example of this is described in the prototype in (Verpoorten, Glahn, Kravcik, Ternier, & Specht, 2009). This prototype presents to students of virtual learning environments some smart indicators informing them about their activities, achievements and progress in comparison with other peer students.

The *strategy of involving learners in data collection* has been identified in two of the prototypes, it supports learning in the affective and the cognitive domain. This strategy has been used to engage learners into scientific activities, by letting them participate in the data-gathering phase of the scientific process. Learners use sensor measurements to gather this data. An example of this strategy is the prototype in (Heggen, 2012). This prototype allows learners to create scientific experiments that are compiled into mobile applications. These applications use the sensors of the mobile devices to assist the learners to conduct their experiments.

Seventeen prototypes have been identified to support the psychomotor domain of learning (see Table 2.3). For the exploration of this domain we analyzed how the prototypes give support on the six categories of the psychomotor domain of learning (Harrow, 1972), identifying support in four of them: *fundamental movements*, *skilled movements*, *physical activities* and *non-discursive communication*.

Table 2.3 Overview of the support for learning in the psychomotor domain.

Category Supported	Amount of Prototypes	Example of Sensors Used
Reflex movements	0	-
Fundamental movements	7	Accelerometers, Cameras, ECG, Electromyography sensor, Gyroscopes
Perceptual	0	-
Physical activities	1	Heart-rate monitor, Thermometer
Skilled movements	7	Accelerometers, Cameras, Force gauge, Gyroscopes
Non-discursive communication	2	-

Seven of the prototypes present support to *fundamental movements*, such as walking, running, sitting, *etc.* The purpose of these prototypes is to help patients going through a rehabilitation process. These prototypes use sensors to track the patients' movements, analyze these movements and give feedback to the patients informing them whether the movements have been performed correctly or incorrectly. As an example, the prototype in (Brunelli, Farella, Rocchi, Dozza, Chiari, & Benini, 2006) uses wearable inertial sensors to identify the posture of patients who are going through rehabilitation after a damage of their motor system. Whenever the posture is incorrect the prototype provides audio feedback.

Support for learning *skilled movements*, referring to the movements used for dancing, recreation and sports, has been recognized in seven of the prototypes. The strategy used to support the skilled movements is similar as the one used to support the basic ones, prototypes use sensors to track the learner's movements, analyze how they are being performed and show the analyzed results to the learner. The areas of this type of learning assistance that have been identified are: music gestures (Bevilacqua, Guédy, Schnell, Fléty, & Leroy, 2007; Van Der Linden, Johnson, Bird, Rogers, & Schoonderwaldt, 2011), special rehabilitation exercises (Kranz, Holleis, Spiessl, Schmidt, & Tusker, 2006), taekwondo movements (Kwon, & Gross, 2005), snowboarding (Spelmezan, & Borchers, 2008; Spelmezan, Jacobs, Hilgers, & Borchers, 2009) and karate punches (Takahata, Shiraki, Sakane, Y., & Takebayashi, 2004).

The prototype in (Vales-Alonso et al., 2010) is the only one that has been recognized to support *physical activities*. This prototype uses sensors to track the weather conditions and current fitness of cross-country runners. According to the difficulty of the route, the tracked weather conditions and the tracked current fitness level of the runner, the prototype indicates the runner the route to take for an optimal workout.

Support for learning non-discursive communication referring to the acquisition and development of nonverbal communication skills has been identified in two of the prototypes. The prototype in (Hoque, Courgeon, Martin, Mutlu, & Picard, 2013) tracks the facial gestures, voice intonation, volume and speaking rate giving feedback to the learner about the correct use of her nonverbal communication for job interviews. The prototype in (Cockburn, Bartlett, Tanaka, Movellan, Pierce, M., & Schultz, 2008) is a videogame that tracks the facial expressions in children with autism teaching them how to smile.

Classification for Formative Assessment Support

To explore how sensor-based learning support can contribute to the solution of one current educational challenge (Geyde, 2010; Russel, 2008), we studied how the investigated prototypes can bring assistance to the implementation of key aspects of formative assessment. By looking at the information that the prototypes gave to the users we identified 51 of them (see Table 2.4) contributing to at least one of these aspects.

Table 2.4 Support for the aspects of formative assessment.

Aspects of Formative Assessment	Number of Prototypes	Strategies Used	Example of Sensors Used
Knowledge of subject matter	12	Presenting sensor data about the learner's performance	Accelerometers, Cameras, Gyroscopes, Software sensors
Knowledge of criteria and standards	15	Presenting sensor data about the learner's performance. Presenting sensor data about the learner's physiological state	Accelerometers, Cameras, EEG, Heart-rate monitors, Galvanic skin response sensor, Gyroscopes, Software sensors
Attitudes toward teaching	2	Informing the tutor about the emotional state of the learner while performing learning tasks	Camera, Galvanic skin conductance, pressure mouse, accelerometers
Skills in setting	8	Setting assessments according to learner's location Setting assessments according to learner's physiological state	GPS, EEG, Heart-rate monitors, NFC, RFID, Software Sensors
Evaluative skills	4	Evaluating answers of learners	GPS, NFC, RFID, Software Sensors
Sharing learning expectations	0	-	-
Self-Assessment	6	Presenting an overview of the learner's performance	Accelerometers, GPS, Software sensors
Peer-Assessment	0	-	-
Feedback	35	Presenting information about the learner's performance, behavior or state	Accelerometers, Cameras, EEG, Heart-rate monitors, Galvanic skin response sensor, Gyroscopes, Software sensors

Twelve of the prototypes have been identified to support the aspect of *knowledge of subject matter*, which allows experts on making better assessments about the students' performance. This support is achieved due to the monitoring capabilities of sensors. The sensor data presented to the experts (tutors), helps them to analyze and identify the errors of the learner. This type of support is used in sports and healthcare. An example of the sports field is found in the Swimming prototype (James et al., 2004). In this prototype, wearable accelerometers are attached to the learner. The data received by these sensors allow for the analysis and error identification of the learner's swimming technique. In healthcare the prototype in (Greene et al., 2010) uses wearable gyroscopes to analyze the gait of patients. This analysis allows detecting gait abnormalities or deteriorations to identify the presence of diseases and pathologies.

The *knowledge of criteria and standards*, which helps to identify the current learning level of the student, is supported by 16 of the prototypes. The strategy of using sensors to track the learner's performance and to identify his errors, which can be used to support *knowledge of subject matter*, can also be used to identify the current learning level of the learner. Two of the prototypes identify the current level of the learner by identifying his physiological state. The prototype in (Szafir, & Mutlu, 2013) uses an electroencephalogram to track the attention level of the learner while attending an online lecture. The prototype shows in which part of the lecture the attention of the learner decreases allowing tutors to give tasks to the learner of the subjects in need of being reviewed. The study in (Bevilacqua et al., 2007) describes a prototype that emulates musical sounds according to certain gestures of the users. In this study teachers who observed students using the prototype, reported that the prototype allowed them to identify the musical level of the students.

We identified two prototypes tracking the emotional state of the learner while doing learning tasks and informing the tutor about this (Arroyo et al., 2009; Littlewort et al., 2011). This helps the tutor to increase her empathy towards the learner and therefore supports the key aspect of formative assessment identified as *attitudes toward teaching*.

Support for *skills in setting,* which deals with the capacity to set assessments that reveal the knowledge and skills level of students, has been identified in eight prototypes. Four of these prototypes support these aspects by setting assessments to the learners in a spatial context. The prototype in (Chen, & Huang, 2012) acts as a mobile guide in a museum. It identifies the location of the learner using RFID technology, and according to the location it asks specific questions to the learner and evaluates her answers. Two of the prototypes support *skills in setting* by tracking the physiological state of the learner. These prototypes display this state to the tutor, allowing them to set appropriate assessments according to the learner's identified state. The prototype in (Hester et al., 2006) exemplifies this. It uses wearable accelerometers to track the movements of patients following a rehabilitation program after having a heart stroke. The analysis of the tracked movements allows doctors to select the right set of exercises and therapy for them. The last identified technique to support skills in setting has been used by two of the prototypes. Here learners are required to use sensors to complete the tests that tutors have given them. For example, in the prototype in (Heggen, 2012) students have to collect and analyze data using the sensors of their mobile devices to answer the scientific tests set by the teacher.

Four prototypes support the *evaluative skills*. They achieved this support by evaluating the questions that have been previously asked to the learners. The prototype in (Hsu & Ho, 2012) has been designed to evaluate the answers of learners to predefined tests and makes use of an expert system to present learners with the learning objects that relate to their tests' results.

Contribution for *self-assessment*, *i.e.*, structuring opportunities for the student to take responsibility about her own learning, was identified in six prototypes. These prototypes structure opportunities to take responsibility of own learning by showing an overview of the actions and performance of the learner. The prototype in (Consolvo et al., 2008) shows an example of this, by tracking the physical activity of the user and displaying an overview of it in the form of a virtual garden where the amount of life displayed in the garden is represented by the physical activity of the user. By looking at this representation, the learner is able to reflect and take responsibility about its actions. Support for key elements such as: sharing learning expectation, and peer assessment have not been identified in the studied prototypes.

Feedback Analysis

Because of its relevance in formative assessment and learning in general, we decided to dedicate a complete subchapter of this review on the analysis of the feedback given by the prototypes. By analyzing the information presented by the prototypes to the user, we could identify that 35 of them, revealed information about the user's performance, activities or states; therefore we selected them for our feedback analysis in this review. In the following subsections of this review we report our exploration on how the questions for effective feedback (Hattie & Timperley, 2007) have been answered by the prototypes.

Where Am I Going?

The answer to "where am I going?" is related to the goals of the user. Five of the prototypes (see Table 2.5) explicitly display an answer to this question. For example, the user's goal in the prototype described in (Carrol et al. 2013) is to eat healthier and avoid emotional eating. In order to make the user aware of how she stands in respect to her goals, this prototype followed the technique described in (Goetz, 2014) of presenting evidence together with consequences. This prototype shows the overview of the user's eating habits as a tree (evidence), where the color (consequence) of the tree depends on the healthiness of the food intake by the user.

The prototypes described in (Consolvo et al., 2008; Froehlich et al., 2009) used the same technique. The first prototype shows an overview of the healthy activities performed by the user (evidence) as a garden where the amount of flowers and life in the garden (consequence) depend on the amount of physical activities. The second prototype uses the same approach but the metaphor used is the one of an ecosystem. The life of the ecosystem depends on the ecological friendly trips done by the user.

The relevance to answering the question of "where am I going?" by sensor-based platform has been empirically tested in the work in (Hsieh, Li, Dey, Forlizzi, & Hudson, 2008). This work has released two different versions of their prototype. Only one of the versions has presented the user with an overview of her standing in respect to her goal. The results of this study show that the compliance to finish sampling experiences in experience sampling method studies was 23% higher in the group whose participants used the version of the prototype displaying the overview.

Table 2.5 Prototypes answering to "where am I going?".

Prototype	Topic	Strategy Used to Answer the Question
Carroll *et al.*, (2013)	Healthy eating	Evidence: Overview of eating habits represented as a tree. Consequences: The color of the tree changes.
Consolvo *et al.*, (2008)	Healthy living	Evidence: Overview user's activities represented as a garden. Consequences: Life in the garden depends on the activities.
Froehlich *et al.*, (2009)	Eco-traveling	Evidence: Overview of means of transportation as an ecosystem. Consequences: Life in the ecosystem depends on the means.
Hicks *et al.*, (2010)	Healthy habits	Ask questions about performed activities to reflect about goals.
Hsieh *et al.*, (2008)	Physical activities	Evidence: Overview of user's performance presented together with the goals.

How Am I Going?

To answer the question of "how am I going?" the sensor-based platforms are required to track the actions or behaviors of the users, and provide them with information relative to their performance in relation with some predefined rules. Twenty-six of the analyzed prototypes have answered this question (see Table 2.6). The analysis in this section discusses the *form* and the *channel* of feedback given by the studied prototypes.

Form of feedback: Looking at the dimension of complexity of feedback (Mory, 2004), feedback can be given at five different levels including no feedback, simple verification, correct response, elaborated feedback and try again feedback. From the analyzed prototypes one of them gives exclusively a *simple verification* feedback giving the user points when guesses about her glucose levels are correct (Pentland, 2004). Eight of the prototypes present exclusively the "try again" feedback, telling the user that her action was wrong and letting her to repeat the action until it is performed correctly. Six of the prototypes give both the simple verification and the try again feedback. In (Paradiso, Morris, Benbasat, & Asmussen, 2004) this has been achieved by playing harmonic sounds when the gait of the users is correct (simple verification) and by playing strong rhythmic sounds pointing out to the user that its gait needs to be corrected (try again feedback).

Ten of the prototypes present elaborate feedback indicating why the performance of the user is correct or incorrect. To give this feedback, the prototypes present the evidence of the user's actions together with indications of the acceptable standards to conduct her activities. An example of this is the prototype described in (Kwon, Gross, 2005). This prototype points out the differences between the movements of an expert martial artist (correct technique or correct standard) and the user, letting the user become aware on how to correct her mistakes. The prototype described in (Hicks et al.,

2010) used a different feedback strategy, showing that our proposed framework to analyze the feedback of sensor-based platforms to the question of "how am I going?" was not exhaustive. This prototype instead of indicating the user whether her behavior has been correct or incorrect, it presents her with evidence of her tracked behavior and asks her a question about it, presenting her a chance for self-reflection.

Table 2.6 Prototypes answering to "how am I going?".

Prototype	Topic	Strategy Used to Answer the Question	Channel of Feedback
Aukee *et al.*, (2004)	Incontinence	Elaborate feedback	Visual
Baca, & Kornfeind, (2006) Biathlon	Rifle movements in Biathlon	Elaborate feedback	Visual
Baca, & Kornfeind, (2006) Rowing	Exerted forces in rowing	Elaborate feedback	Visual
Baca, & Kornfeind, (2006) Table tennis	Shot position and cadence in table tennis	Elaborate feedback	Visual
Bevilacqua *et al.*, (2007)	Musical level	Try Again Simple verification	Audio
Brunelli *et al.*, (2006)	Posture	Try Again	Audio
Burish, & Jenkins (1992)	Relaxation	Try Again Simple verification	Audio
Carroll *et al.*, (2013)	Healthy eating	Elaborate feedback	Visual
Cockburn *et al.*, (2008)	Teaching to smile	Try Again Simple verification	Visual
Hicks *et al.*, (2010)	Healthy habits	Questions are asked user letting the user reflect about the answer.	Visual
Hoque *et al.*, (2013)	Interview coaching	Elaborate feedback	Visual
Kranz *et al.*, (2006)	Physiotherapy	Try Again	Audio Visual
Kwon & Gross (2005)	Martial arts	Elaborate feedback	Visual
Lehrer *et al.*, (2000)	Breathing technique	Try Again	Audio
Li *et al.*, (2012)	Coordination training	Try Again Simple verification	Audio Visual
Linden *et al.*, (1996)	Attention level	Try Again	Audio Visual
Paradiso *et al.*, (2004)	Gait	Try Again Simple verification	Audio
Pentland (2004) Diabetes	Diabetes	Simple verification	Audio
Spelmezan & Borchers (2008)	Snowboarding	Try Again	Audio
Spelmezan *et al.*, (2009)	Snowboarding	Try Again	Haptic
Strachan (2005)	Sound navigation	Try Again	Audio
Takahata *et al.*, (2004)	Martial arts	Try Again Simple verification	Audio
Vales-Alonso *et al.*, (2010)	Cross country running	Elaborate feedback	Visual
Van der Linden *et al.*, (2011)	Violin Playing	Try Again	Haptic
Verhoeff *et al.*, (2009)	Gait	Elaborate feedback	Audio
Verpoorten *et al.*, 2009 [56]	Indicators for virtual learning environments	Elaborate feedback	Visual

Seven studies reported empirical results about the use of the prototype with participants, all of them showing positive results in regards to the purpose of the prototype. Five of these prototypes used the strategy of *try again feedback* (Linden et al. 1996; Van der Linden et al., 2011; Spelmezan et al., 2009, Burish, & Jenkins 1992, Verhoeff et al., 2009) and two of them presented elaborate feedback (Hoque et al., 2013; Aukee et al., 2004)

Channel of feedback: Since users receive the feedback through their senses, in theory there is a feedback channel for each one of them: visual, auditory, haptic, gustatory and olfactory. The feedback channels used by the prototypes were audio, visual and a combination of both. Ten of the analyzed prototypes present their feedback exclusively through the audio channel. The prototype developed in (Takahata et al., 2004) has shown an example of this; the sounds played by the prototype depend on the accuracy of the karate punch technique performed by the user. Eight of the prototypes display their feedback through the visual channel. The prototype in (Carroll et al., 2013) uses the screen of the user's mobile device to show a message saying: "let's count slowly to 10 and breath…". The combination of visual and audio has been used in three prototypes. In (Linden et al., 1996) the prototype shows the score of the user on the computer screen and plays sounds whenever the user maintains her concentration. Two of the prototypes provided feedback through the haptic channel. The prototype in (Van der Linden et al., 2011) exemplifies this type of feedback. It consists of a pair of gloves that give haptic feedback when the user, who is learning how to play the violin, performs incorrectly a specific technique.

Empirical positive results in regards to the purpose of the prototype were found for all of the identified feedback channel practices (Linden et al., 1996; Van der Linden et al., 2011; Spelmezan et al., 2009; Hoque et al., 2013; Aukee et al., 2004; Burish, & Jenkins 1992; Verhoeff et al., 2009). Pointing out that the study of (Spelmezan et al., 2009) showed that for physical activities such as snowboarding, the haptic feedback was perceived faster than the audio feedback.

Where to Next?

The answer to "where to next" is about showing 'some' guidance to the user on the next steps to follow. Eight prototypes have been identified which present the user an answer to this question (see Table 2.7) Five of the prototypes present an indicator of just the next step to take, indicating the next step to do to solve a problem (Anderson, & Reiser, 1985), showing the steps required to correct mistakes (Chen, & Huang, 2012), showing the next activity to engage (Pentland, 2004), instructing the user the steps that she needs to follow in order for her to relax and gain self-control again during highly emotional situations (Carrol et al., 2013), and showing which direction to take (Vales-Alonso et al., 2010). Three of the prototypes present the user with a complete personalized learning path for them. This path has been obtained by capturing the user's attention levels during a virtual lecture (Szafir, & Mutlu, 2013), tracking the user's competences (Hsu, & Ho, 2012), or identifying the user's learning styles (Dung, & Florea, 2012). While the prototype in (Szafir, & Mutlu, 2013) has just pointed out the user the steps to follow, the prototypes described in (Dung, & Florea, 2012; Hsu,

& Ho, 2012) have used system adaptation techniques to present the user with her personalized path. The system adaptation technique presented by (Dung, & Florea, 2012) uses a literature-based approach, where the number of visits and time spend by the students working with learning objects is used to automatically identify the student's learning style. This approach tracks the behavior of students in order to get hints about their learning style preferences, then it uses a rule-based approach to estimate the preferred learning style from the amount of matching hints. Finally, it presents the learner with a learning path suited for his learning style. None of the prototypes have shown empirical results about their learning support.

Table 2.7 Prototypes answering to "where to next?".

Prototype	Strategy Used to Answer the Question
Anderson & Reiser (1985)	Informs the user which next step to take.
Carroll *et al.*, (2013)	Informs the user which next step to take.
Chen & Huang (2012)	Presents a corrective step to follow.
Dung & Florea (2012)	Presents a personalized learning path.
Hsu & Ho (2012)	Presents a personalized learning path.
Pentland (2004) Memory glasses	Informs the user which next step to take.
Szafir & Mutlu (2013)	Points out the steps to follow.
Vales-Alonso *et al.*, (2010)	Tells the user which direction to take.

Discussion

The pairing of sensors with software components has created tools with capabilities to automatically retrieve and analyze data, referred to in this review as sensor-based platforms. In order to explore the use of these tools in learning, we analyzed the prototypes described in literature according to our classification framework. Starting with an exploration of the areas of learning that have been supported by sensor-based prototypes, this review revealed that sensor-based platforms have been designed and used to give support in each of the three learning domains. The domain with the most support (56 of the 82 studies) is the cognitive domain; mirroring what happens with learning in general, where the cognitive domain is the most used and studied (Wirth, & Perkins, 2007). Remarkably, also given the research in (Van Merrienboer, & Kirschner, 2007), which asserts that a comprehensive educational design should merge these domains, in this review we could only identify two prototypes supporting a combination of domains. This presents a research opportunity on finding the implications to create sensor-based platforms able to support multiple domains of learning.

In our search to seek whether sensor-based platforms can be used to help solving current educational challenges, we continued our analysis of the prototypes studying their possible connection with formative assessment. While in this review we did not identified prototypes specifically designed to give formative assessment, our analysis showed that sensor-based platforms have already been used for seven of the nine aspects of formative assessment described in our classification framework (see Table

2.4). The missing aspects for contribution were structuring opportunities for peer assessment and sharing learning expectations.

With the intention to deepen our research in an aspect considered to be fundamental for learning and for formative assessment, our analysis of the prototypes showed that sensor-based platforms are able to retrieve, measure and analyze personal information in order to give feedback on the three questions of effective feedback. For giving an answer to the first question, "Where am I going?", which deals with guiding learners towards their goal, we identified three different used representations. These representations consisted of a description of the learners' goals, showing the learners' performance together with the consequences, and showing a metaphor of the goals and performance instead of the real data values. While we recognize ways to give an answer to this question, we did not found prototypes attempting to formulate an advice on it. Additionally, none of the reviewed articles studied the appropriate timing for giving this type of feedback. An important aspect for answering the question of "where am I going?" which besides relating to the metacognitive skills of a self-regulated learner one of its main purposes is to keep the learner motivated, therefore having an impact on the affective domain of learning. As previously seen in the analysis of the learning domains, the affective domain of learning does not receive as much attention as the cognitive domain, which partly can explain the knowledge gaps on how to use sensor-based platforms to answer "where am I going?".

Continuing with the second question, this review shows that sensor-based platforms have been used to give an answer to "how am I going?". We recognized several feedback representations used by sensor-based platforms to answer this second question. These representations can be classified according to different feedback dimensions (Mory, 2004) such as: timing of feedback, feedback channel and complexity of feedback. However, what we miss from the reviewed articles was a study revealing a suitable method to present this answer as feedback to the learner. From the reviewed articles only three of them (Van der Linden et al., 2011; Spelmezan et al. 2009; Paradiso et al., 2004) present an explanation for the selection of its feedback method. Overall, also in relation to the other two questions discussed, studies about the effectiveness of the different feedback channels and feedback dimensions are limited, finding only one work (Spelmezan et al., 2009) comparing the receptivity between the auditory and the haptic feedback channel. Moreover, no study has been identified exploring how the different ways to give feedback using sensor-based platforms, play a role in subjects such as the cognitive load (Paas, Renkl, & Sweller, 2004), reflection-in-action and reflection-on-action of the learner (Schön, 1993).

The review shows that sensor-based platforms can be used to show the users their next learning steps, therefore answering the question of "where to next?". What we miss to recognize in the literature is a prototype able to answer the three questions of effective feedback.

This analysis allowed us to identify two main research branches for sensors-based learning support. The first branch deals with the acquisition of relevant data that might be useful for the learner, and the second branch deals with the presentation of this sensor data to the learner. The amount of different prototypes supporting learning for so many different subjects and domains has shown us that several researches have already been undertaken on the acquisition of relevant sensor data for learning. However, we did not identify many studies investigating and reporting on the implications to deliver this relevant inferred sensor data in ways that can effectively support learning. Looking that only 35 out of 82 prototypes have been identified to present the learner with feedback reveals this. Furthermore, we found only one study (Spelmezan et al., 2009) analyzing different types of feedback methods for their prototypes, and only in few cases the selection of the feedback methods used by the prototypes were argued. This research gaps give us an indication of the state-of-the-art of sensor-based learning support, which can be corroborated by the very few empirical studies found investigating the effectiveness of sensor-based platforms as learning tools. This current state of research in sensors and learning is also reflected in related literature reviews studying the topic of sensors, where the purpose is to analyze these platforms based on techniques to identify objects (Atzori, Iera, & Morabito, 2010), achieve ambient intelligence (Aztiria, Izaguirre, & Augusto, 2010), augment reality (Carmigniani, Furht, Anisetti, Ceravolo, Damiani, & Ivkovic, 2011), create body sensor networks (Garg, Kim, Turaga, & Prabhakaran, 2010), classify postures and movements using wearable sensors (Ugulino, Cardador, Vega, Velloso, Milidiú, & Fuks, 2012), etc. None of the literature studies known to the authors focus on the use of sensors to support learning. These findings about the current maturity of sensor-based learning support align with the lack of use of sensor-applications for formal learning, which are not that popular yet and only deal with the presentation of sensor data for the study natural sciences (Globisens, 2015; PASCO, 2015; Vernier Software, 2015) together with the arrival to the market of sensor applications such as Nike+ (Nike +, 2014), Digifit (Digifit, 2014), Xbox fitness (Xbox fitness, 2014) etc. that support informal learning.

Conclusion

In this review we analyzed 82 prototypes found in literature studies according to our classification framework in order to identify the state-of-the-art of sensor-based learning support. The analysis revealed sensor-based learning support as an emerging and promising field of study, which has the potential to support learning in several areas and subjects. In this review we merely identified research studies focusing on the learning aspects of the described sensor-based platforms. This turned out to be a limitation for this review, by not allowing us to clearly identify and analyze the learning strategies used by the prototypes. Nevertheless, this lack of focus on learning effectiveness, points out a research direction for further improvement on the state-of-the-art of sensor-based learning support.

This review shows that the focus on sensor-based applications for learning support is quite broad and that this support can have an effect on all the learning domains. It also shows the potential for sensor-based platforms to contribute on the implementation of formative assessment. Nevertheless, we found a lack of studies focusing on the implications required for sensor-based platforms to present their inferred information in such ways that learners can assimilate it effectively, so that sensor-based platforms can become effective learning tools. This research gap suggests the main research path to follow for the improvement of sensor-based learning support. By following this path, we consider that sensor-based platforms can become reliable learning tools able to reduce the workload of human teachers and therefore contribute to the solution of a current educational challenge, which is the implementation of formative assessment. While more work needs to be done on sensor-based platforms to become common learning tools introduced to formal and non-formal learning programs, this review can be taken as a basis and inspiration towards this goal.

Part II

First Iteration

Findings from the literature study revealed that the feedback of sensor-based applications was mostly limited to a binary signal, emitted whenever the learner's performance goes outside of some predefined parameters. Moreover, the learning effects of these applications were hardly ever studied. To address this issue and contribute to the field of sensor-based learning support the remaining research of this thesis followed a design-based research approach focusing mostly on exploring how to make sensor-based feedback effective for learning a complex skill. Constrained by the context of the Metalogue project the chosen skill for the exploration of sensor-based learning support was public speaking. This first iteration explores how, in the form of immediate feedback, the inferences made by sensor-based applications can effectively be communicated to learners.

Chapter III

Stand Tall and Raise your Voice! A Study on the Presentation Trainer

The Presentation Trainer (PT) was developed with the aim to study how sensors can be used to provide learners with immediate and effective feedback. The PT is a tool that captures and analyses in real time some nonverbal communication aspects of the learner, and displays the results of this analysis as feedback to the learner. This chapter presents the first two user studies on the PT. The studies showed that participants would gladly use the PT to prepare for oral presentations, and pointed out some considerations required for the design of tools able to effectively support a complex learning task through immediate feedback.

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Introduction

Public speaking is a subject that has been studied for ages. The earliest identified vestiges about a systematical study of the art of public speaking comes from the ancient Greeks and are about 2500 years old (DeCaro, 2011). Nowadays public speaking is required for almost any profession (Parvis, 2001) and has an influence on many aspects of our daily life (DeVito, 2014)[3].

In a presentation, the speaker has the purpose to communicate her message to the audience. In order to do that successfully she has to be able to encode the message in the right format and deliver it effectively (DeVito, 2014). The nonverbal communication of the speaker plays an important role in the delivery of the message (DeCoske, & White, 2010); Trimboli, & Walker, 1987; Bjerregaard, & Compton, 2011).

While currently it is possible to get access to different material such as seminars, courses, books, magazines, etc. that can teach us how to use our nonverbal communication effectively for public speaking, developing these skills requires practice and feedback. Having a human tutor to give us feedback is not always affordable or feasible, making it relevant to explore how technology can be used to solve this learning problem.

Sensors have shown to be a technology able to provide learners with feedback for many different learning applications (Schneider, Börner, van Rosmalen, & Specht, 2015), therefore we use them to develop the *Presentation Trainer*: a sensor-based prototype designed to support the development of nonverbal communication skills for public speaking.

In order to create an effective trainer for a complex task such as the development of nonverbal public speaking skills, we need to overcome technical challenges such as how to accurately track and interpret the nonverbal communication of the user. As well as educational challenges such as how to use the analyzed information to provide users with the kind of feedback that will help them with the improvement of their skills. Therefore, we decided to follow a design-based research methodology (Anderson, & Shattuck, 2012), which includes user tests at the end of each iteration providing us with guidance for the upcoming ones. The purpose of this paper is to present our findings from the two studies that have been conducted in our process of developing the *Presentation Trainer*.

Presentation Trainer Application

The *Presentation Trainer* is a tool designed to support learners in the development of their nonverbal communication skills for public speaking, by giving them feedback and instruction about the use of their voice and body language. The approach followed for its development is an iterative one, where each iteration is evaluated through user tests. The two versions of the *Presentation Trainer* presented in this article were implemented

3 http://www.nsaspeaker.org/

in Processing 2.1[4], an open source JAVA-based programming language. It has an OpenGL integration that allows fast graphic manipulation making it suitable for 2D and 3D programs. To track the learner's performance the Presentation Trainer makes use of the Kinect Sensor[5] and the computer integrated microphone.

Feedback Framework

Feedback is one of the most influential learning tools; learners' achievements both positive and negative vastly depend on it (Hattie, & Timperley, 2007). The means to present feedback vary greatly and several dimensions of feedback have been identified. One of these dimensions refers to the timing of feedback, which can be delayed or immediate (Mory, 2004). While training for public speaking, immediate feedback has been proven to have a superior influence in the development of the nonverbal communication skills (King, Young, & Behnke, 2000). The channel of feedback is another feedback dimension that we considered to be relevant for our designs. While giving a presentation, the presenter is constantly receiving feedback from the audience through the visual channel, also the most important nonverbal communication aspect while presenting is giving eye contact to the audience (Bjerregaard, & Compton, 2011). Therefore the *Presentation Trainer* gives immediate feedback that is transmitted through the visual channel, implicitly helping the user to learn how to receive feedback while giving a presentation.

Voice Analysis

To track the user's voice the *Presentation Trainer* uses the integrated microphone of the computer together with the Minim audio library[6]. By analyzing the volume input retrieved from the microphone it is possible to give instruction to the user regarding her voice volume and speaking cadence. Having a good voice volume modulation while public speaking is fundamental to transmit a clear message and keeping the audience attention (DeVito, 2014). Therefore the *Presentation Trainer* gives feedback to the user when the volume of her voice has been too loud, too low or has not been modulated for an extended period of time.

Pauses are referred as a stop while speaking. Mastering them is an important skill for public speaking (Bjerregaard, & Compton, 2011). When used correctly, pauses allow the audience to take a breathe when information is dense in content or emotion, create spaces for the audience to refocus on the given information, prepare the audience for the following subject, and can add dramatic emphasis during the presentation. To help with the improvement of this skill the *Presentation Trainer* gives feedback about the proper use of pauses, indicating the user when it is time to pause and start talking again. The default values used by the Presentation Trainer to give these indications

[4] https://www.processing.org/

[5] http://www.xbox.com/en-US/kinect

[6] http://code.compartmental.net/tools/minim/

have been obtained by analyzing the average speaking and pausing time of 15 different Ted Talks.[7]

Body Language Analysis

The *Presentation Trainer* uses the Microsoft Kinect sensor in conjunction with the OpenNI SDK[8] to track and analyze the body of the user. This fusion allows the creation of a skeleton representation of the user's body. With the use of this skeleton representation, the *Presentation Trainer* is able to analyze the user's body posture and movements in order to give feedback and instructions. While speaking to an audience it is important to project confidence, openness and attentiveness towards the audience. The body posture of the speaker is a tool to convey those qualities. Therefore it is recommended to stand up in an upright position facing the audience and with the hands inside of the acceptable box space; in front of the body without covering it, above the hips, and without the arms being completely extended (Bjerregaard, & Compton, 2011). We defined these rules in terms of the relative coordinates between the different tracked limbs of the user. Following these rules the Presentation Trainer is able to give feedback about the user's posture.

Hand gestures in public speaking enhance a speech in different ways such as: strengthening the audience's understanding of verbal messages, painting vivid pictures in the listeners' minds, conveying the speaker's feelings and attitudes, dissipate nervous tension, enhance audience attentiveness and retention, etc. (Toastmasters International, 2011) The current version of the *Presentation Trainer* does not identify specific gestures; nevertheless it gives feedback to the user whenever she is not using any gesture for a certain amount of time. In order to identify whether the user has been gesturing or not, the Presentation Trainer calculates the amount of movement of the user's hands.

First Study

The purpose of this first study was to explore the users' acceptance of the *Presentation Trainer* and to identify its usability challenges as an immediate feedback tool for learning. This section includes a description of the first version of the *Presentation Trainer's* output interface, a description of the setup used for our first user tests, and a report of our findings

Output Interface Version 1

The output interface that has been used for the first user tests of the *Presentation Trainer,* was designed as a dashboard, it contains three columns with a total of seven different feedback modules (Figure 3.1).

[7] https://www.ted.com/talks
[8] http://www.openni.org

Each of the feedback modules located on the columns at the left and the right side of the interface, provide feedback on only one aspect of the user's nonverbal communication. They present their feedback using a circle whose colors fade indicating whether the user is performing correctly or not. In the case when a mistake is detected, these modules show a written instruction on how to correct it. The modules on the left column give feedback about the user's body posture and hand movements; and the modules on the column give feedback about the user's voice volume and speaking cadence.

The center column contains three feedback modules that continuously reflect the user's actions, highlighting her mistakes. The module at the top shows a skeleton representation of the user, highlighting the limbs that are in an incorrect position. The module in the middle shows a graph mirroring the users voice. Finally the module at the bottom indicates the amount of hand movement performed by the user.

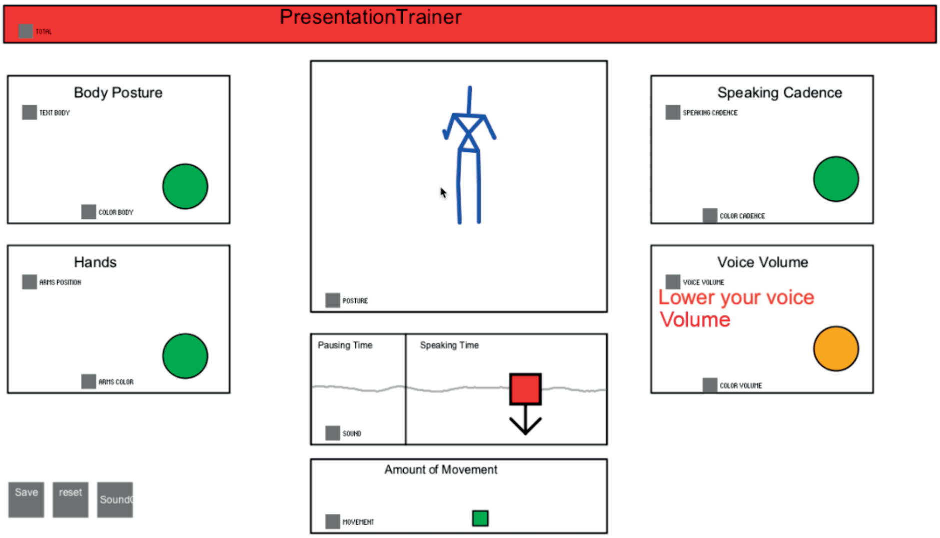

Figure 3.1 Presentation Trainer interface showing that the user was speaking too loud.

User Tests Setup

The test consisted on doing a trial short presentation while using the *Presentation Trainer* as a coach. The experimental setup sketched in Figure 3.2 shows the participant standing at a distance of approximately 2.5 meters in front of the Microsoft Kinect and 2 computer screens. One of the screens displayed the *Presentation Trainer;* the other displayed the slides that had to be presented. We deliberately chose to use two screens for the setup, because we wanted to simulate a real presentation scenario, where the presenter has to pay attention to the presented slides and to the audience.

After the trial presentation, participants were asked to fill in a System Usability Scale (SUS)(Brooke, 1996) questionnaire followed by an interview. During the interview we showed the user interface of the Presentation Trainer to the participants and asked them questions to find out which components of the interface were the most used, helpful and interesting. We also asked questions on their general opinion about the Presentation Trainer and what they would like to get from it in the future.

Results of the First User Study

Six participants took part on the test we considered this amount reasonable since the recommended number of participants for user tests is five (Nielsen, & Landauer,1993). We had three female and three male participants, whose ages ranged from 24 to 45 years old. The working experience of all of them is in the field of learning or computer sciences. Moreover, as part of their work, they have to perform public presentations a couple of times a year. In a scale from 0 to 100 where 100 represents the best value, the average scores for the SUS were: 67.5 for SUS, 77.1 for learnability, and 65.1 for usability (Lewis, & Sauro, 2009).

All participants concluded that the most observed modules where the ones located in the center column paying a special attention to the one showing the Skeleton. The colored circles were observed but participants did not know how to change their behavior based on them. The users did not observe the displayed texts with instructions. Some participants suggested using icons instead of the circles to make the feedback more explicit.

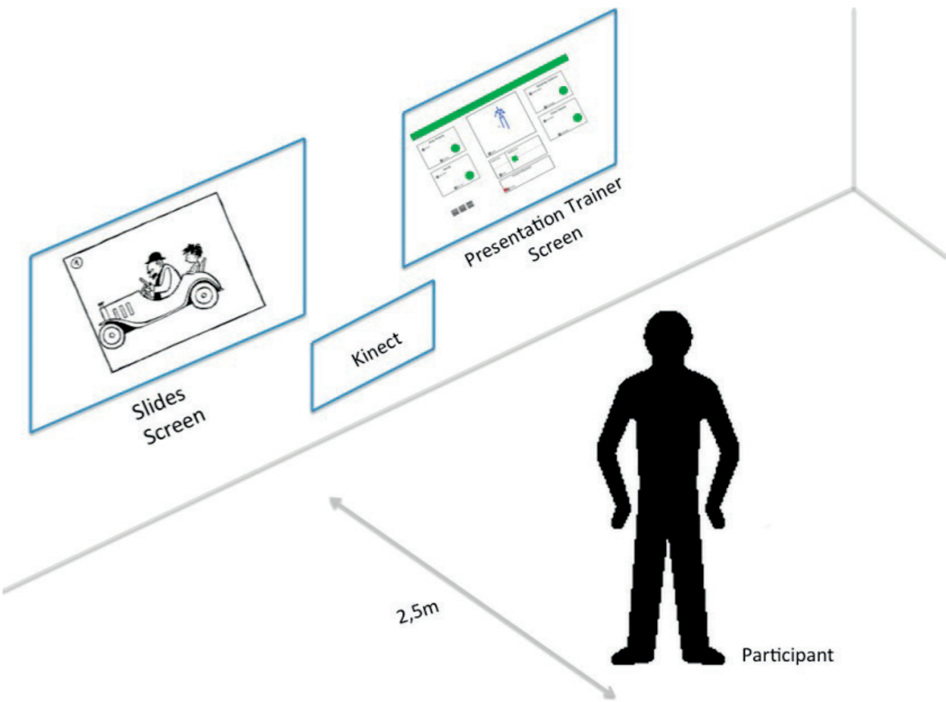

Figure 3.2 The setup sketch of the first user test

Participants remarked about the overload of attention required to give a presentation and be aware of all the feedback at the same time. Therefore it was suggested to use a learning strategy focusing on giving feedback only about on one aspect of the trained skills at the time.

Evaluation of First Results

Participants in the user tests show great enthusiasm towards using a tool such as the Presentation *Trainer* to practice for their future presentations. The observations executed during the user tests showed that participants did not always adapt their behavior according to the feedback presented by the tool. We attribute this lack of responsiveness mainly to the amount of cognitive load required to give a presentation, which constrains the amount of attention that can be paid to the tool. Hence, we can conclude that an immediate feedback interface for learning needs to be carefully designed, in order for it to be effective.

Second Study

For this study we created a second version of the *Presentation Trainer,* carefully redesigning it according to the challenges exposed by our first evaluation. In this second study we conducted again some user tests exploring the impressions, interactions and challenges of the second version of the *Presentation Trainer*. This section describes the approach used to improve our prototype, including the description and results of our second user study.

Tackling the complexity

Our first study showed that the amount of attention that a learner can pay to feedback while giving a trial presentation is quite constrained. To tackle this problem we decided to follow two strategies. The first strategy was to make the task of training for a presentation simpler for the user by the implementation of an instructional design model on the *Presentation Trainer* that deals with the difficulty of learning complex tasks. The second strategy deals with the improvement of the interface so that users find it easier to act on its feedback.

Instructional Design for Complex Learning
Since developing nonverbal public speaking skills has shown to be a complex learning task, we decided to start implementing the four-component instructional design (4C-ID) model (Van Merriënboer, 1997) in the design of the *Presentation Trainer*. In order to develop complex skills, instructional design models usually divide the complex skill, into sub-skills and teach these sub-skills separately. The 4C-ID also encourages a holistic approach with realistic, complete tasks so learners can understand the relevance of these sub-skills in the whole task (Van Merriënboer, & Kirschner, 2013).

To start with the implementation of the 4C-ID model, for this version of the trainer we created two modes:

- The *Freestyle Mode* with the purpose to allow learners to develop integrated knowledge while practicing a real life task, which is giving a presentation.
- The *Exercise Mode* for sub-skills practice.

Freestyle Mode

This mode has the purpose to let users practice the real life task (giving a presentation) while receiving feedback and instruction from the *Presentation Trainer*. It has the same functionality as the previous version of the tool, by standing in front of the Microsoft Kinect and speaking, the user will start to receive immediate feedback and instruction about her nonverbal communication. We called it *Freestyle Mode* because in this mode users are not restricted to perform specific tasks.

Our previous study showed us that the complexity of the previous version of the *Presentation Trainer* should be reduced in order for users to assimilate its feedback. Before making drastic changes on the interface, for this study we wanted to explore whether a nicely and clearly designed dashboard interface (Figure 2.3) is practical for this type of learning scenarios.

Figure 3.3 Freestyle Mode Interface

To improve on the interface modules for Body Posture and Hands were merged into one module responsible to give instruction about the user's posture, including the posture of the hands and the body. In order to reduce the amount of possible instructions that the user can get about her posture, such as: uncross your arms, straighten up, look forward, do not hide your left hand behind your body, etc.; we decided to let the system tell the user to *Reset Posture*. The *Reset Posture* is a posture used by many public speakers, where they stand straight, facing the audience, with their legs uncrossed, their hands in front of their body, above their hips, and letting the fingers of the right hand touch the fingers of the left one (Figure 2.4).

Figure 3.4 Examples of influential speakers standing in the Reset Posture

For immediate feedback the use of keywords have shown to be more effective than the use ad hoc explanations (Coninx, Kreijns, & Jochems, 2013) therefore we shortened the text instructions from the feedback modules to maximum two word phrases such as: Reset Posture, Move More, Pause, Speak, Raise Volume, Lower Volume, and Modulate Volume.

In the first version the users commented that they noticed the color changes in the circles but did not understand how to respond. Additionally they suggested the use of icons instead of circles. Therefore this new version substituted the circles with icons fading their color from white when everything is correct to red when the user is making a mistake on the corresponding aspect of her nonverbal communication.

Additional changes in the interface deal with the skeleton representation, which changed into an enhanced mirrored image of the user. This image highlights user's limbs that are in a wrong position. Also the *Voice Feedback* module changed into a voice histogram, allowing the user to have an overview about the volume of her voice and how much has been talking.

Exercise Mode

To implement the sub-skills practice defined in the 4C-ID model we created the exercise mode for the *Presentation Trainer*. This mode fractionates the task of developing nonverbal public speaking skills into different exercises or learning tasks. Each exercise is designed to train the user in a specific sub-skill of her nonverbal communication. Each exercise provides the user with information that highlights its relevance, instructions explaining the steps that the user is supposed to follow at the precise moment and feedback about her current performance (Figure 2.5).

The exercises developed so far are: Reset Posture, Voice Volume, Hands Gesticulation, Pause Control, Leaning in while speaking soft, and Questions and Answers section. The Reset Posture exercise should get the user acquainted with the Reset Posture, a posture that is commonly used by well-trained presenters that allows them to be perceived open and attentive towards the audience. During this exercise the user is asked to go back to the Reset Posture after speaking for a few moments.

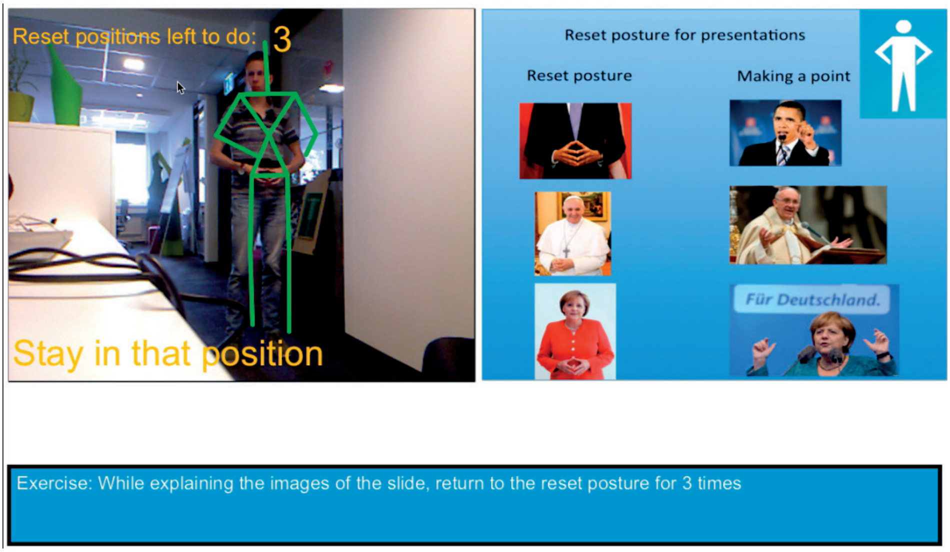

Figure 3.5 Interface of Reset Posture exercise. Top Left: Enhanced Mirror. Top Right: Sample slide to use for the exercise. Bottom: Exercise instruction.

The *Voice Volume* exercise intends to make the user aware of the importance of modulating her voice volume while public speaking. It asks the user to speak using different voice volumes for a predefined amount of time.

The *Hand Gesticulation* exercise aims at training the use of hand gestures that are inside of the acceptable box space, while teaching the importance of using these types of gestures. In these exercise the image mirror of the user is shown in the screen, and the user is asked to reach certain virtual targets with their hands while speaking, helping her to automate the use of hand gestures while doing a presentation.

The *Pause Control* exercise has the purpose to teach and train users about the proper way to use pauses while public speaking. In this exercise the user is instructed to speak for some seconds and then make a pause that is at least 2 seconds long, before instructing her to start speaking again.

In the previous exercises the purpose was to either train the body language or the voice. In the *leaning in while speaking soft* exercise we explore the combination of training both aspects at the same time. The *technique of leaning in and speaking soft* can be used in public speaking to help you to connect at a personal level with the audience while sharing some secrets or personal opinions (DeVito, 2014). So this exercises instructs the user to lean in and speak at a low voice volume for some seconds. After performing the exercise correctly the *Presentation Trainer* instructs the user to return to the *Reset Posture* in order to restart the exercise.

The purpose of the *Questions* exercise is to teach users to keep composure, while waiting for questions asked by an audience and answering them. During this exercise the user has to stand in the *Reset Posture* waiting for the *Presentation Trainer* to ask a question. The questions asked by the *Presentation Trainer* are related to the already trained nonverbal communication practices for public speaking. An example question is: "What are the benefits of pauses while public speaking?" Once the user answers the question, the *Presentation Trainer* instructs the user to stay quietly in the *Reset Posture* while waiting for the next question. The Presentation Trainer does not assess the answer to the questions; it only assesses the nonverbal communication of the user while waiting for the questions and answering them.

Second Study User Tests Setup

Prior to the test participants were asked to create six slides of a short presentation based on a template that was proportionated to them beforehand. The template includes topics such as the participant's origin, profession, personal hobbies and favorite movies.

Upon the arrival to the test, the participant was asked to sign up a form of consent to confirm the agreement that the recordings done during the test were going to be used only for academic purposes. After that we gave each participant a briefing about the purpose of the *Presentation Trainer* and explained the tasks to be done during the test.

Each user test consists of two phases. On the first phase the participant had a session using the *Exercise Mode* of the *Presentation Trainer*. In this session the participant followed the instructions provided by the Presentation Trainer, that guided him/her through the six different exercises: *Reset Posture, Voice Volume ,Hand Gesticulation, Pause Control*, *Leaning in while speaking soft*, and *Questions*. In order to move from one exercise to the next the participant had to perform the exercise correctly three times. The experimental setup for this phase consisted on the participant standing at approximately 2.5m in front of the Microsoft Kinect sensor and a 27-inch display displaying the *Presentation Trainer* interface. Once completing all the exercises, the participant was asked to start with the second phase of the test. For this second phase, the participant stood 2.5m in front of the Microsoft Kinect sensor, a 27-inch display showing the *Presentation Trainer* interface on *Freestyle Mode,* and another screen showing the slides of the presentation (figure 3.2). During this phase of the test, the participant was asked to give a trial presentation of the prepared slides, while paying attention to the feedback from the *Presentation Trainer*.

After completing the two phases of the test, the participant was asked to fill in a SUS questionnaire followed by an interview. During the interview the examiner asked about:

- Personal impressions of the *Presentation Trainer*.
- Opinions about the *Exercise Mode*.
- The added value of the Presentation Trainer in contrast of preparing for a presentation in front of a mirror without any tool giving feedback.
- Additional comments and suggestions.

The tests and the interviews were recorded in order to make a proper analysis of the results.

Results of the Second Study

To make this study comparable with the previous one, we decided to recruit participants from the same age and background as in the first user test, and who never used the Presentation Trainer before. The amount of participants for these tests was five, three females, and two males. Once again the age of the participants ranged from 24 to 45 years old, they all worked also in the field of learning or computer sciences, and have to give oral presentations a couple of times a year. In a scale from 0 to 100 where 100 represents the best value, the results of the SUS questionnaire gave the Presentation Trainer an average of 57.0 in the SUS, 59.4 in usability and 47.5 in learnability (Lewis, & Sauro, 2009).

All participants during the interviews stated that the load of attention for giving a presentation and using the system for the first time is too much to handle, therefore they all indicated that would need some time to get used to the tool before being able to assimilate the feedback and instructions provided by it. All participants pointed out that they perceived the Presentation Trainer as a useful tool and that they would like to use it in order to prepare for their upcoming presentations. Pointing out the relevance of receiving objective immediate feedback while preparing for them.

With regard to the Exercise Mode, all participants found this mode necessary to develop their nonverbal skills. Nonetheless, they remarked on improving the tutorial for each of the exercises. Two participants made a suggestion about making the feedback while performing the exercise more explicit, by giving clear indications on how to correct their current behavior when the exercise is being performed incorrectly.

During this user study we observed that the feedback provided by the *Presentation Trainer* had some effects on the participants' behavior, nevertheless this change of behavior was not always the desired one. For example when the *Move More* caption was presented, users shook their body or took one or two small steps to the sides, instead of gesticulating more with their arms while speaking. We also identified that all participants mastered the *Reset Posture* by using it throughout their trial presentation, providing us an indicator that some learning has happened while using the system.

Discussion of Second Study

The scores of the SUS questionnaire were considerably lower than in the previous study, this might give the impression that the older version of the trainer was more usable and learnable than the new version. However, in contrast with the tests of the previous study where participants did not change their behavior while receiving feedback from the trainer, during the tests of this second study participants modified their behavior when feedback and instruction was given to them. Also we found it very encouraging observing all participants using the *Reset Posture* while giving their presentation, suggesting us that some learning took place while using the *Presentation Trainer*. These observations indicate us that the trainer became more usable and learnable even when users perceived the opposite. We attribute the lower SUS scores to two different factors. The first one is that while giving the trial presentation, participants were able to identify in the feedback proportionated by the *Presentation Trainer* that there was something wrong with their performance, but that the feedback was not clear enough for them to know how to correct their mistakes. This led them to realize about the time needed to learn how to use the system correctly. The second factor deals with the expectations of the participants towards the Presentation Trainer. We explain these increasing expectations to the fact that the interface of this second tested version does not look like a prototype anymore, leading participants to expect from the *Presentation Trainer* to work as a commercial system and not as a experimental prototype.

Examining the impressions and observations of the use of the *Freestyle Mode*, we can conclude that the cognitive load is an important issue that needs to be further tackled. We observed that a clear interface allows users to perceive and adapt to some of its feedback. Showing us that a dashboard interface could be used to give immediate feedback for learning, but with some limitations. To make full use of this type of interfaces a user needs to pay attention to all the elements displayed on the screen and identify how to follow them; in order to be able to adapt her behavior and learn something, while performing a complex task. This requires an amount of a cognitive load that surpasses the capacity of the user.

We also observed that while using the Freestyle mode, in some cases participants were able to perceive the feedback, but adapted their behavior in an incorrect way. This pointed out the importance of adding a learning module to the system, explaining the meaning of the feedback and teaching users, the proper way to interpret it.

The Exercise Mode looks really promising; nonetheless it has room for improvement. Feedback showing whether the exercise is being performed correct or incorrect should become more explicit, and should give clear instructions on how to correct the mistakes. Exercises need to be well designed so that users are able to transfer the skills acquired during the exercises to the presentations. For example as shown during the tests, participants learned how to gesticulate, but not how to gesticulate while presenting. This was reflected during their trial presentations where none of them used enough hand gestures while presenting.

Conclusion and Future Work

The rising availability of sensors has created the space to design, develop and explore tutoring tools able to provide users with immediate feedback about their performance.

In this article we present the findings of our ongoing studies on the *Presentation Trainer*: An example of a sensor-based tutoring system that by providing users with immediate feedback and instruction, is able to support them with acquisition and development of complex skills. The two studies described in this article showed us that users seem to be really enthusiastic and open towards the new learning experiences that this type of tools can provide. Furthermore, they also provided us with three findings that serve as guidelines for the design of this type of learning tools:

- Regardless of the explicitness of the feedback, the user requires an explanation on how to respond to it, before starting her training using the tool.
- The interface should be simple and clear; a dashboard giving feedback in multiple aspects at the same time is not optimal for learning.
- Decreasing the complexity of a learning task, by following the principles of an instructional design model helps users to assimilate the feedback given by the system, allowing them to learn specific skills. As the participants of our tests show by using the *Reset Posture*.

We consider that the learning effects of the *Presentation Trainer* and any other immediate feedback tool depend partly on their usability; therefore for near future work, we plan to continue with our current design-based research approach; keep on developing and conducting user test with the upcoming versions of the *Presentation Trainer*, until we consider it mature enough to test its learning effects on users. Furthermore we will conduct interviews with experts in the field of public speaking in order to come up with valid expertise model to analyze the nonverbal communication for presentations, and study the experts' opinion on how a tool such as the *Presentation Trainer* can be used to support the development nonverbal communication skills.

Chapter IV

Can you help me with my pitch? Studying a tool for real-time automated feedback

The study of the previous chapter pointed out some considerations for the design of effective sensor-based immediate feedback. Based on these considerations a new feedback mechanism for the PT was developed. This new feedback mechanism provides learners with a maximum of one feedback instruction at a given time. Once the feedback is displayed it remains being visible until the learner corrects the mistake, then it waits some time before displaying a next instruction if needed. This chapter describes an empirical study that tested the effects of the PT's feedback on learners who used the tool while practicing for an elevator pitch. Results from this study reveal that the feedback has a significant effect on the learners' motivation, confidence, self-awareness and performance.

This chapter was published as: Schneider, J., Börner, D., Van Rosmalen, P., & Specht, M. (2016a). Can You Help Me with My Pitch? Studying a Tool for Real-Time Automated Feedback. *IEEE Transactions on Learning Technologies*, 9(4), 318-327. doi: 10.1109/TLT.2016.2627043

Introduction

Feedback is one of the most significant interventions in learning (Hattie, & Timperley, 2007). The effects of this feedback depend on a variety of variables of the different dimensions the feedback can have (Mory, 2004). For the particular case of public speaking, feedback is a key aspect for learning and developing the respective skills (Van Ginkel et al., 2015a). The effectiveness of this feedback depends on various variables. For example, feedback provided by a tutor in combination with feedback provided by peer students has proven to be more effective than feedback provided only by a tutor (Mitchell, & Bakewell, 1995). Regarding the timing of feedback, studies have shown that for aspects that can be corrected immediately, such as eye contact and body posture, immediate feedback is more effective than delayed feedback (King et al., 2000). However, having tutors or peers providing us with feedback whenever we have time to practice is neither an affordable nor a feasible solution. To support this kind of learning outside of the traditional classroom setting, we developed the Presentation Trainer (PT). The PT is a sensor-based tool designed to support the development of basic public speaking skills, by providing learners with immediate feedback about different aspects of their nonverbal communication. In this article we report on a study on the impact that the feedback given by the PT had on participants training for an elevator-pitch[9].

Background

Using computer systems to support learners with personalized feedback and instruction is a practice that has been around for several years now. A classical example of this type of systems is the LISP Tutor, which appeared in 1983 and was designed to give real-time feedback to learners of the LISP programming language (Corbett, & Anderson, 1992). The adaptation and feedback of computer-based learning support was based on user-modeling approaches taking into account performance information on tasks given in the learning environment. In recent years, advances in technology have made it possible to consider sensor information and interaction of users in context for learning support (Zimmermann, Specht, & Lorenz, 2005). The coupling of sensors with multimodal computer interfaces made it possible to track and automatically analyze users' actions (Ghasemzadeh, & Jafari, 2011) and physiological states (Bahreini, Nadolski, & Westera, 2016). This led to the research and development of feedback systems able to support learners in a vast number of learning activities (Schneider et al., 2015a) that cover the cognitive, affective and psychomotor domain of learning (Bloom et al., 1956).

In the study described in this article we investigate how tutor systems with sensing capabilities can support the development of nonverbal communication skills. Tutor systems presenting support for these skills have already been studied for scenarios such

[9] https://en.wikipedia.org/wiki/Elevator_pitch

as job interviews (Baur, Damian, Gebhard, Porayska-Pomsta, & André, 2013; Hoque, et al., 2013) and public speaking (Damian, Tan, Baur, Schöning, Luyten, & André, 2015; Tam, MacLean, McGrenere, & Kuchenbecker, 2013; Batrinca, Stratou, Shapiro, Morency, & Scherer, 2013; Schneider, Börner, van Rosmalen, & Specht, 2015b). These public speaking tutor systems use different approaches and focus on different aspects. The prototype in (Damian, et al., 2015) used wearable technologies, e.g. the Google Glass, to present the user with feedback for specific nonverbal communication factors while giving a presentation. The study in (Tam et al., 2013) explored the use of an armband that provided haptic feedback to the user about the timing of her presentation whereas (Batrinca et al., 2013) designed an environment to help learners to overcome their public speaking anxiety by giving presentations in front of a virtual audience. In addition, this system is also able to make an assessment of some nonverbal aspects of the presentations. However, an evaluation of this assessment is not described in their work. In the work of (Schneider et al., 2015b) the authors explored a tool, which provided learners with immediate feedback about some nonverbal communication aspects while practicing their presentations. In addition, the tool was augmented with exercises focusing on specific elements. While the study revealed that the students were eager to use the system, it also showed that the dashboard interface employed was too difficult to follow while practicing for a presentation.

To expand on the state of the art of tutor systems for public speaking and study the effects such a system can have on learners, we developed and evaluated the Presentation Trainer.

Presentation Trainer

The Presentation Trainer (PT) is a multimodal tool that supports learners with the self-practice of basic nonverbal communication skills for public speaking. It uses sensors to track the learners' body and voice to provide them with feedback about a set of basic nonverbal communication aspects for public speaking. Grounded on the results from related work, we decided to develop the PT based on the following assumptions:

- Immediate feedback is proven to be more effective for training nonverbal communication (King et al., 2000).
- The amount of cognitive load needed to practice for a presentation makes it difficult for the learner to pay attention to all the different elements simultaneously displayed on a dashboard interface. This makes dashboard interfaces far from ideal for immediate feedback for practicing public speaking skills (Schneider et al., 2015b).

Taking into account these two assumptions, the version of the PT described in this article has the capability to analyze the user's performance, and to select accordingly at most one nonverbal communication aspect to be presented as a feedback intervention.

Presentation Trainer Architecture

The PT has been developed in C# using the .NET framework 4.5. To capture the user's voice and body the current version of the PT uses the Microsoft Kinect for Windows V2 and its proprietary SDK. Its architecture shown in Fig. 1 has four main functionalities: Nonverbal Communication Tracking, Nonverbal Communication Analysis, Feedback Selection, and Feedback Transmission.

In order to track the user's nonverbal communication, the PT is constantly listening for new sensor data obtained from each sensor channel and stores this sensor data in their corresponding pre-Analysis object. The PT has a channel for audio and a channel for the body of the user. Connected to these channels, it has an Audio pre-Analysis and a Body pre-Analysis object. The Audio pre-Analysis object has a 0.64 seconds long audio buffer that stores at a frequency of 16 kHz, the absolute volume values obtained from the microphones of the Microsoft Kinect for Windows V2. This object also contains a Boolean variable indicating whether the user is currently speaking. To infer whether the user is speaking or not the PT compares the average volume value of the buffer against isSpeaking threshold. If the average volume value is bigger than the threshold, the Boolean variable that indicates whether the user is speaking is set to true. The Body pre-Analysis object stores at a rate of 30 frames per second the current coordinates of the detected joints from the user's body. It also contains Boolean variables for all the postures that have been considered important for the analysis of the user's nonverbal communication for public speaking. If a posture is identified then its respective Boolean variable is set to true.

The JudgmentMaker object does the Nonverbal Communication Analysis. It analyses the data from the pre-Analysis objects in order to identify nonverbal communication mistakes or good practices. Whenever a specific mistake or good practice is identified the JudgementMaker creates a Presentation Action object and stores it on a list. If a Presentation Action is no longer identified, the JudgmentMaker removes it from the list.

The RulesAnalyzer is the object responsible for the Feedback Selection. It makes certain about the appropriate timing to present feedback. If timing is appropriate, it selects the oldest identified Presentation Action from the list of Presentation Actions, and triggers a feedback event about it. Whenever RulesAnalyzer identifies that the selected Presentation Action has been removed from the list, it triggers a correction event. The Application Controller of the PT receives the events and forwards them to the connected output channels that transmit the feedback to the users.

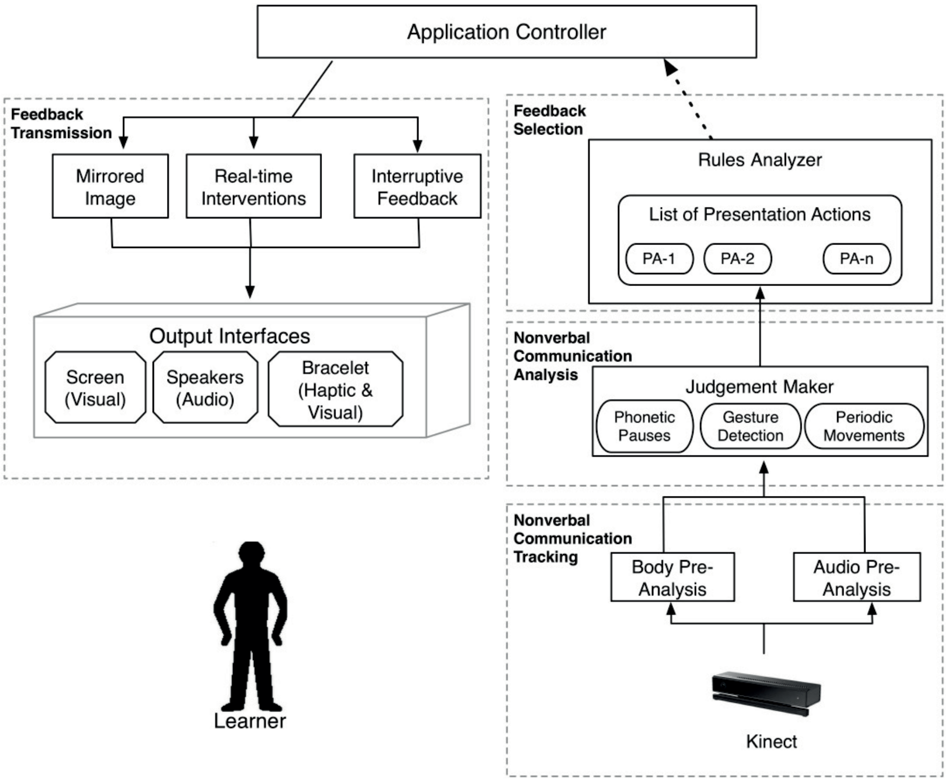

Figure 4.1 Presentation Trainer Architecture

Presentation Trainer Feedback

The current version of the PT supports the training of basic public speaking skills, i.e. by providing learners with feedback about their use of pauses, voice volume, body posture, use of gestures, use of phonetic pauses, and steadiness in body posture. This set of nonverbal communication factors has been based on a synthesis of factors that according to public speaking manuals and courses affect the quality of a presentation (Bjerregaard & Compton, 2013; DeVito, 2014; Toastmasters International, 2011), and we found them sufficient to study the feedback of the PT. Currently the PT is programmed to identify only mistakes in this set of factors. Whenever a mistake is identified, a Presentation Action is created. Next, we will discuss one by one each of the aspects we identify.

Good voice volume modulation in public speaking helps to communicate the message clearly and to keep the audience attention (DeVito, 2014). The PT uses the microphone from the Microsoft Kinect V2 to capture the voice volume of the learner. In the case where the PT perceives the voice volume as too soft or too loud, it creates a Voice Volume Presentation Action. To infer whether the speaking volume is too soft or too loud the PT follows the next procedure. It captures the sound through the use of a microphone at a rate of 16 kHz and stores the absolute volume values in a 0.64 seconds long buffer. Then it compares the average value of the buffer against three thresholds that can be manually set up during runtime to adapt to the acoustic needs of the room where the PT is being used. These thresholds are: speaking threshold, soft speaking threshold and loud speaking threshold. A soft volume Presentation Action is created when the average volume of the buffer is in between the speaking threshold and the soft speaking threshold. A high volume Presentation Action is created when the average volume is above the loud speaking threshold.

Using pauses correctly is a very important skill for public speaking (Bjerregaard & Compton, 2013). The appropriate use of them allows the audience to take a breath when information is dense in content or emotion. Pauses also prepare the audience for the next subject, and are able to add some dramatic emphasis during the presentation. To identify a pause the PT has an isSpeaking volume threshold, volume values below that threshold are considered as silence. A pause is identified whenever the average value of the volume buffer remains below the isSpeaking threshold of a period longer than 0.25 seconds. Assessing the correct moment to pause during a presentation is highly dependent on its content e.g. pausing at the end of a sentence, after a rhetorical question, etc. The aim of the PT's feedback regarding the use of pauses is to remind and make the learner aware about pausing while presenting, instead of pointing out the learner about the precise moment to pause. Therefore, whenever the PT does not detect a pause after the predefined time of 15 seconds, it raises a Presentation Action about pauses. We came up with the times of 0.25 seconds and 15 seconds by analyzing the average speaking time and pausing time of 15 different Ted Talks.

The speaker's body posture helps to convey confidence, openness and attentiveness towards the audience. To convey these attributes it is recommended to stand up with an open posture, straight, facing the audience, with the hands always visible inside of the acceptable box space and preferably above the hips (Bjerregaard & Compton, 2013). The PT uses the Microsoft Kinect sensor V2 to track the learner's body. This body tracking presents the PT with the coordinates of the learner's joints. These coordinates are later used to infer the learner's body posture. Even when the learner stays still, these coordinates still flicker, however the flickering obtained by the Microsoft Kinect V2 is usually not big enough to interfere with the posture identification of the learner We apply a time threshold to improve the level of accuracy for posture identification, it helps to distinguish between postures and movements. The threshold is experimentally determined to be 0.3 seconds. This means that the PT recognizes a posture if the tracked body coordinates of the learner remain inside of some predefined posture values for a period longer than 0.3 seconds. Whenever the recognized posture violates the preset posture rules, the PT generates a body posture Presentation Action.

Hand gestures are a powerful tool to communicate your message in public speaking. They are able to enhance a speech by: painting vivid pictures in the listeners' minds, conveying the speaker's feelings and attitudes, enhance audience attentiveness and retention, dissipate nervous tension, etc. (Toastmasters International, 2011). In the current version, the PT is not able to identify specific gestures. It is only able to recognize whether the learner uses gestures while speaking. To do this, the PT uses input of the Microsoft Kinect sensor V2 to get the coordinates of the learner's joints and keeps track of the angles between forearms and arms, and between arms and shoulder blades. The PT notices the decrement and increment of these tracked angles. If angles start increasing and stop decreasing, or the opposite way around, stop increasing and start decreasing a "pre-gesture" is identified. A gesture is recognized when the total increment or decrement of the "pre-gesture" angles are greater than 5°. This strategy of identifying gestures has proved to be very accurate. Because even with the constant flickering of body coordinates tracked by the Kinect sensor, the angle change between the tracked user's limbs is never greater than 5° when the user is not moving. Moreover, when using gestures the difference in angles are always far greater than 5°. A Presentation Action about gestures is created whenever the user is speaking, and no new gestures appear for a predefined time set to six seconds. We set the predefined time to six seconds because while tuning the PT, we observed that people who stay longer than six seconds without using gestures generally continue the presentation without using them at all, and that a gesture rarely takes longer than six seconds to be completed.

The phonetic pauses or filler sounds are all the "ehm", "hmm", "aah", etc. sounds made by the speaker. These sounds show hesitation, which is not a good practice for public speaking, therefore during the Toastmasters gatherings it is common to have an Ah-counter indicating the speakers how many times they have used a filler sound. The PT uses the speech recognition capabilities of the Microsoft Kinect V2 to recognize some of this filler sounds. The current accuracy for the PT to recognize these filler sounds is about 20%. This accuracy level is quite low, however we consider it satisfactory enough to remind users about this type of mistake. It is possible to increase this accuracy level but at the moment this would translate into the detection of false positives. Whenever the PT recognizes a filler sound it creates a phonetic pause Presentation Action.

By examining several presentations of novice speakers and interviewing teachers in public speaking, we identified that a common mistake that novice speakers make is to switch weight from one leg to the other, showing nervousness, a lack of confidence and giving the impression that they are dancing during their presentations. To track this behavior the PT uses the Microsoft Kinect sensor V2 to track the X and Z coordinates of the learner's hips. The PT uses a counter to take note of the number of swings from these coordinates, every 4 seconds this counter is reset. If the PT identifies 3 or more swings in 4 seconds, it creates a Presentation Action about staying grounded.

The PT stores all the current identified Presentation Actions on a list and deletes the ones that are no longer detected. This strategy of generating Presentation Actions whenever a rule is detected makes the PT scalable, allowing the inclusion of new type of "nonverbal mistakes" and "good practices" for updated versions of the tool.

Once the current Presentation Actions are identified, the PT is able to present the learner with feedback about their nonverbal communication. The amount of cognitive load (Sweller, 1994) required from the learner while practicing for a presentation is quite high. The learner needs to know their topic (what to present and how to structure it) and how to deliver it (how to use their voice e.g. pitch, speed or volume, body, etc). Therefore we need to carefully design a feedback mechanism, that can actually help the learner to become aware of her nonverbal communication, adapt it, and use this increased awareness to improve her skills (Schneider et al., 2015b). The main graphical interface of the PT constantly shows a mirrored image of the learner with the purpose to support the raise of self-awareness. When considered necessary, the PT transmits to the learner on top of this a feedback-instruction. To limit the cognitive load at most one feedback-instruction is given at a time. This feedback-instruction is currently transmitted through a visual and haptic channel, since research has shown that as the cognitive load increases more redundant multimodal communication is needed (Ruiz, Chen, & Oviatt, 2009). The visual feedback is displayed through the graphical interface of the PT on top of the mirrored image of the user. To transmit the feedback through the haptic channel, we developed a Feedback Wristband (FW) (Figure 4.2).

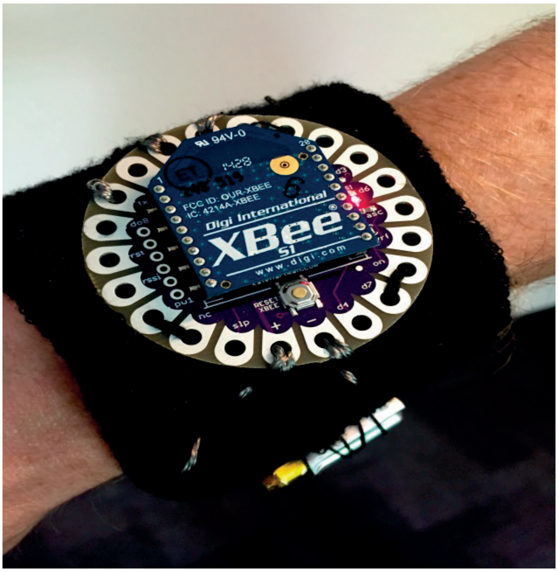

Figure 4.2 Wristband used for haptic feedback

This FW can be connected to the PT via Bluetooth. Whenever a feedback intervention is triggered, the PT sends a signal to the FW. At this time the FW produces a small vibration indicating the learner to pay attention to the screen, because a Presentation Action has been identified.

The procedure executed by the PT to provide the user with feedback is the following:

First the PT checks for the appropriate time to present feedback to the learner. A small user study conducted, indicated that a constant stream of feedback, even when it was only one type of feedback at the time, resulted in too much confusion for the users. Therefore, the current version of the PT waits at least six seconds after the last feedback stopped being shown, in order to consider it appropriate to give new feedback to the user.

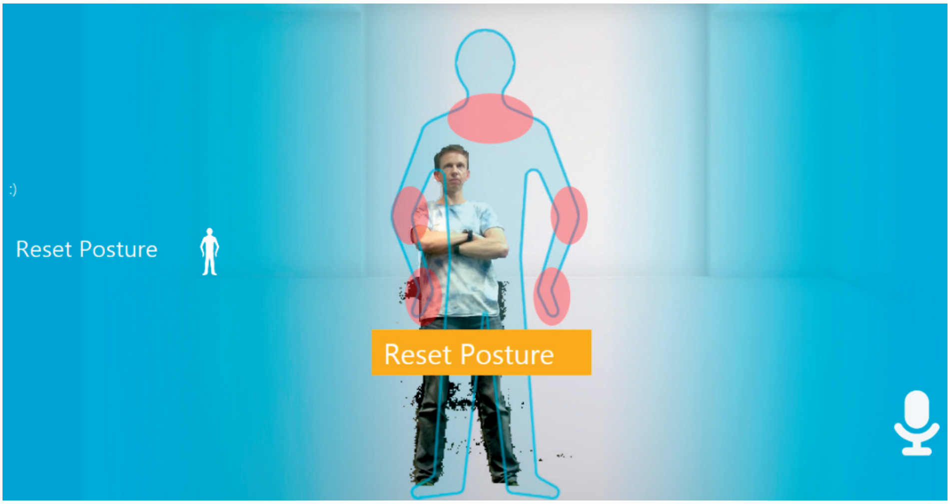

Figure 4.3 Immediate corrective feedback for crossing arms

Once the time to give feedback is appropriate, the PT looks at the list storing the current Presentation Actions. In the case the list is not empty, the PT selects the Presentation Action to be shown. Currently the PT uses a FIFO strategy to make this selection. This means that the selected Presentation Action is the one that has been for the longest time in the list. After making this selection, the PT decides whether the feedback should be corrective or interruptive. Corrective feedback indicates that a Presentation Action has been identified. This type of feedback produces in real-time a small vibration in the feedback wristband, and is visually displayed on top of the mirrored image of the learner. The feedback instruction displayed shows an icon and a short (maximum two words long) written instruction indicating how to correct the identified mistake (Figure 4.3). This feedback icon remains on the screen until the mistake is corrected. When the mistake is corrected a check mark appears in the screen, the feedback icon and instruction fade away, and the appropriate time to show a new feedback starts its countdown.

In the case that a mistake is not corrected after 20 seconds or that a mistake has been repeated several times (currently set to 5) the PT presents the user with interruptive feedback. Interruptive feedback produces some vibration, a pause sound, stops the program, and displays on the screen the reason of the interruption (Figure 4.4). The interface of the interruption offers the user the option to continue practicing the presentation receiving feedback on all nonverbal aspects, or only on the aspect that she was interrupted for, so that she can shift her focus on this specific skill.

Figure 4.4 Interruptive feedback for a long time of crossing arms

Purpose of the study

We conducted this empirical study with the purpose to evaluate the PT as an effective feedback tool for supporting the development of basic nonverbal communication skills for public speaking. To evaluate this effectiveness we explored the influences that the PT's feedback has in terms of learner's perception and learner's performance. For these two aspects we tested the following hypotheses:
Hypothesis 1:

The feedback of the PT will raise the learners' awareness of their nonverbal communication, increase their confidence on their skills, and increase their motivation to be trained.

To test Hypothesis 1 we examined the learners' perception, i.e. we used two questionnaires, one for each phase of the experimental set-up.
Hypothesis 2:

The feedback of the PT has a positive influence in the learners' performance. Learners who trained using the full version of the PT will perform better than learners who trained with the limited version of the PT.

To test Hypothesis 2, we used the log files of the PT and analyzed the evolution of the performance scores from the pitches executed during the training sessions and the performance score of the final unsupported pitch.

Method

In this study we investigated the influence that the feedback of the PT has on learners practicing for an elevator-pitch. An elevator-pitch is a 30 to 120 seconds long speech that summarizes in lay terms what one does and why it is important. We deliberately chose the elevator pitch over other types of presentations because we consider it complex enough for participants to train their nonverbal communication, and short enough to fit in the time constrains of the experiment. To conduct this study we followed a quasi-experimental design (DiNardo, 2010) with a treatment and a control group, where the independent variable used was the feedback of the PT.

Participants

In this study we had a total number of 40 participants. Each group, the treatment and the control group, contained 9 female and 11 male participants. The age of the participants ranged between 24 to 62 years, with an average age of 42.6 years. All participants were professionals working at our university, with a similar western European cultural background. We recruited them by personally asking for their willingness to take part in our experiment. The criteria used to accommodate them in the treatment or control group was randomly based on the number of their experimental session. Participants from odd sessions (1st, 3rd, etc.) were assigned to the treatment group, and participants from even sessions (2nd, 4th, etc.) were assigned to the control group.

Apparatus and Materials

As an intervention tool we used two different versions of the PT. The control group used a limited version of the PT. This limited version of the PT did not provide the users with any feedback intervention; it only displayed the mirror image of the user (Figure 4.5 Left). The treatment group used the full version of the PT described in previous chapters (Figure 4.5 Right).

To measure the effects of the PT's feedback and test our hypothesis we used two questionnaires and the performance data logged by the PT. The first questionnaire is a user experience questionnaire containing three questions. These questions inquire the motivation, perceived amount of learning, and learning experience in comparison with a traditional classroom setting. Answers to these questions are given on a Likert-type scale, whose ranking goes from 1 to 10.

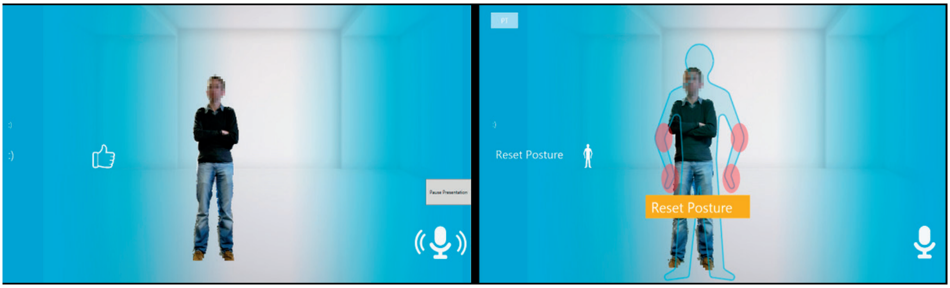

Figure 4.5 Left: PT version for control group. Right: PT version for treatment group

The second questionnaire is a self-assessment and self-awareness questionnaire. This questionnaire contains eight items for self-assessment, six items for self-awareness, and one item about self-confidence. The items of self-assessment ask participants to provide ratings for the overall pitch, the overall nonverbal communication, body posture, use of voice, cadence, staying grounded and phonetic pauses. The ratings for these items are given in a Likert scale with values ranging from 1 to 5. The items about self-awareness ask participants to indicate the perceived amount of body posture, volume, gestures, phonetic pauses, cadence, and grounded mistakes performed during the pitch. Finally, the item of self-confidence asks participants to evaluate their self-confidence about their "elevator-pitch" skills. This evaluation is rated using a Likert scale whose values range from 1 to 5.

To measure the performance of the participants we used the log files generated by the PT during the training sessions and the final pitch. These log files include: the starting and ending time of each training session and pitch, all identified Presentation Actions (mistakes) together with their corresponding starting and ending timestamps, and all Feedback events with their corresponding timestamps.

Procedure

All experimental sessions in this study were individual and were performed following the procedure described in Figure 4.6. Each session started with a five-minute lecture about nonverbal communication for public speaking. The nonverbal aspects taught in this lecture, were the same aspects as the ones tracked by the PT: body posture, use of hand gestures, voice volume, pauses, phonetic pauses, and ability to stay grounded. This lecture had two purposes. The first purpose is to assure that all participants had a similar baseline of basic knowledge about nonverbal communication for public speaking. It is important to clarify that the PT a tool designed to support the practice basic nonverbal communication skills for public speaking rather than a tool designed to teach basic nonverbal communication skills for public speaking. The second purpose of the lecture is to teach assure that people learned about these skills, before they start practicing.

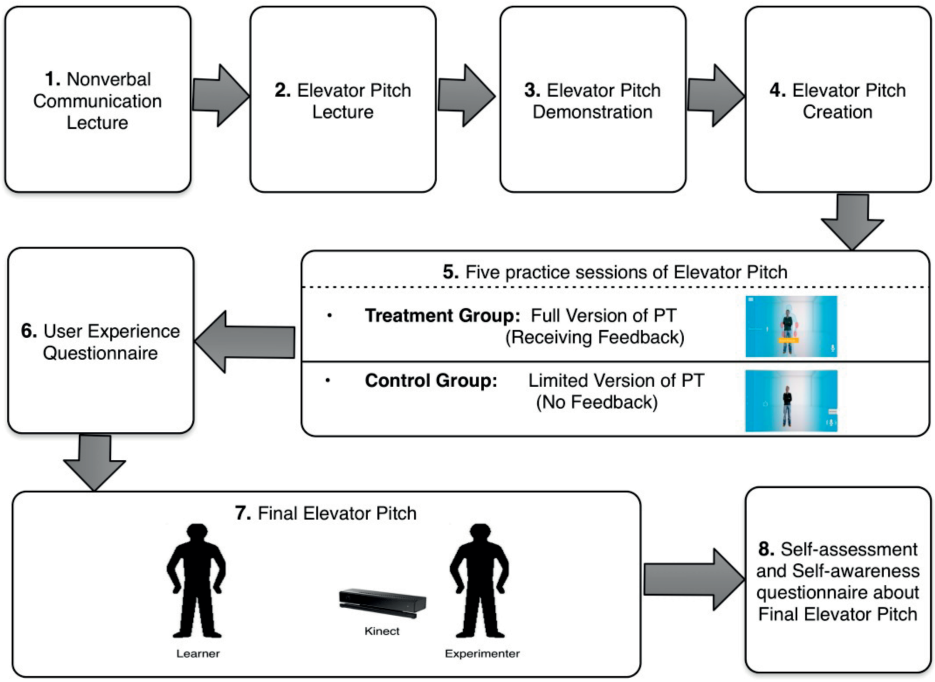

Figure 4.6 Experimental Procedure

Once this lecture finished, participants had another five-minute lecture about elevator-pitches. In this lecture participants learned the basic elements needed to create their own elevator-pitch. This lecture finished with a live example of an elevator-pitch performed by the tutor. As soon as the lectures finished, participants had five minutes to create their own elevator-pitch. Participants were free to use any topic for their pitch.

On the next stage of the test participants practiced the delivery of their recently created pitch. Participants of both groups practiced the pitch in five consecutive training sessions. For these practice sessions participants stood between 1.5m and 3m in front of the Microsoft Kinect sensor and a 50 inches monitor displaying the interface of the PT (Figure 4.7). Participants from the control group practiced their pitch using a limited version of the PT, only showing a mirrored image of the user, without the provision of any feedback. Participants from the treatment group practiced their pitch using the full version of the PT, receiving immediate and interruptive feedback when necessary.

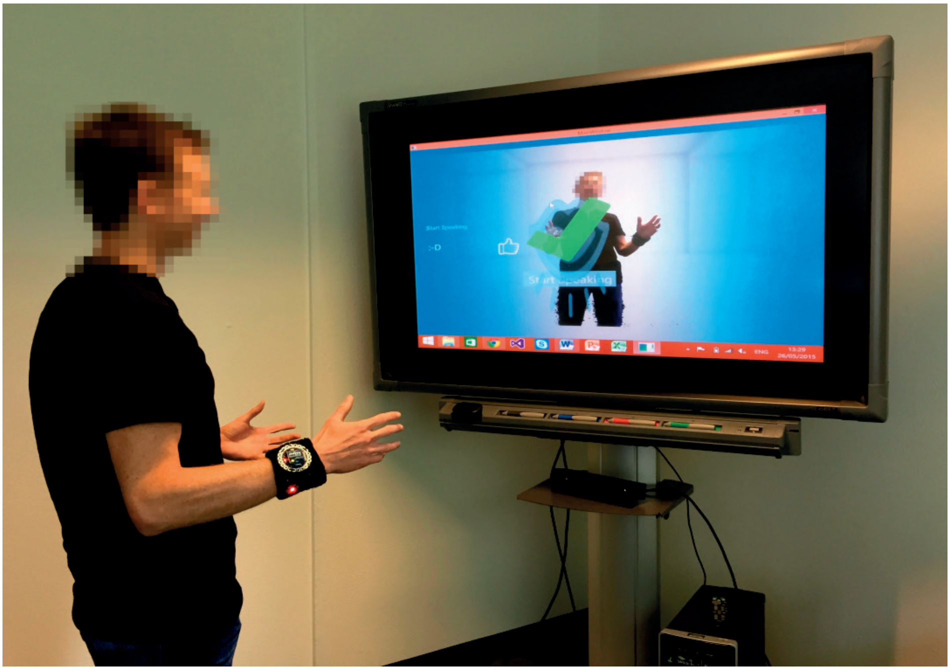

Figure 4.7 Training session setup with the PT giving feedback

After the fifth practice session the participants were asked to answer the user experience questionnaire. In the next phase of the experiment participants had to deliver a final elevator-pitch, without the assistance of the PT. To deliver this pitch participants stood 1.5m to 3m in front of the Microsoft Kinect V2 sensor. Just behind the Microsoft Kinect V2 sensor was the experimenter pretending to be the audience of the pitch, and controlling the PT (starting and ending the pitch session). The PT in this final pitch was used only to log the performance of the participants. The participants were not able to see the interface. The experimental session ended by asking participants to fill in the self-assessment and self-awareness questionnaire about their final pitch.

Results

The average of the answers from the 1st questionnaire regarding user experience are shown in Table 4.1. We used a heteroscedastic t-test to compare the difference between both groups. These results show that participants from the treatment group indicated to have felt significantly more motivated while practicing for their pitch than participants from the control group. The amount of perceived learning from participants of the treatment group was also significantly higher in comparison with the control group. Without significant differences between groups, both groups indicated a positive attitude towards the use of a PT-alike tool in comparison to learning in a traditional classroom setting.

Table 4.1 Average results on the 3 dimensions of user experience extracted from the post session questionnaire (ratings from 1 to 10).

Dimension	Treatment Group	Control Group	t - test
Motivation *10=very motivated	M = 7.89, SD = 2.05	M = 4.47, SD = 1.68	t(26) = 5.62, p < .01
Learning Perception *10=learned a lot	M = 7.47, SD = 1.17	M = 6, SD = 2.42	t(35) = 2.38, p < .05
Practice using PT vs. Classroom *10=much better than classroom	M = 6.94, SD = 1.93	M = 6.1, SD = 2.08	t(36) = 1.29, p = .2

In the final questionnaire the participants assessed their final pitch on Volume, Posture, Gesture, Cadence, Phonetic Pauses, Ability to stay grounded, Nonverbal communication in general, and overall pitch. The results indicated that participants from the treatment group self-assessed themselves with a higher rating than participants from the control group. However, when comparing the difference between both groups using a t-test only the self-assessment ratings for the ability to stay grounded showed significant results between both groups. Using a scale from 1 to 5, scores from the treatment group were ($M = 4$, $SD = 0.86$) against ($M = 2.8$, $SD = 1.00$) from control group; $t(37) = 4.06$, $p < .01$.

To evaluate the self-awareness level from participants we compared the difference between their perceived amount of mistakes during the final elevator-pitch and the amount of mistakes captured by the PT. The average amount of these differences is shown in Table 4.2. Results show that participants from the treatment group were better at making an educated guess about the amount of mistakes made during their last pitch for all the evaluated nonverbal categories with the exception of phonetic pauses.

Table 4.2 Average differences between perceived mistakes and mistakes capture by the PT for the final pitch

Mistake type	Treatment Group	Control Group	t - test
Voice volume mistakes	M = 3.45, SD = 4.03	M = 4.15, SD = 4.5	t(38) = .53, p = .6
Posture mistakes	M = 1.25, SD = 1.07	M = 4.4, SD = 4.25	t(21) = 3.05, p < .01
Gestures mistakes	M = 1.55, SD = 2.44	M = 2.5, SD = 3.19	t(36) = 1.06, p = .3
Cadence mistakes	M = 1.5, SD = 1.3	M = 2.1, SD = 3.59	t(24) = .71, p = .49
Phonetic Pauses mistakes	M = 2.45, SD = 2.5	M = 2.2, SD = 2.01	t(36) = .35, p = .73
Grounded mistakes	M = 0.25, SD = .55	M = 1.7, SD = 2.78	t(20) = 2.29, p <. 05

We added the difference between measured and perceived mistakes for all of the trained categories to get the total difference. We compare this total difference between the treatment and the control group using a t-test. Results of this comparison show significant difference between both groups. The values for the total difference of mistakes for the treatment group were (M = 10.45, SD = 8.06) and the values for the control group were (M = 17.05, SD = 10.99); $t(35)=2.17$, $p<.05$. These results indicate that the feedback of the PT has a positive influence in the user's self-awareness.

Results also show significant differences between both groups in the confidence scores that participants assigned to their elevator-pitch skills. In a scale from 1 to 5 the treatment group scored (M = 3.3, SD = 0.73) and the control group (M = 2.75, SD = 0.85); $t(37) = 2.19$, $p < .05$). These results indicate that the feedback of the PT also has a positive impact in the user's confidence.

According to our criterion, the influence that Presentation Actions have in the quality of a presentation, depend on the percentage of time that they are being displayed throughout a presentation. For example, it is worse to speak too soft throughout the whole presentation, than to speak too soft on several occasions for short periods of time that in total last a fraction of the presentation. Therefore to assess the performance of the participants we used the percentage of Time in Mistake (pTM) for each type of Presentation Action. To measure the pTM we used the logged data generated by the PT on each of the sessions. For each session and each type Presentation Action logged, we added its duration and divided by the total time of the session.

The pTM average values for each of the training sessions on the different Presentation Actions are shown in Table 4.3. For all types of Presentation Actions and training sessions the pTM average values for the treatment were lower than the pTM average values for the control group. In the case of the Presentation Actions regarding voice volume, body posture, hand gestures, and correct use of pauses, the average pTM values for the treatment group decreased throughout the sessions in contrast with the average pTM values for the control group that remained stable. The average pTM values for phonetic pauses and ability to stay grounded were similar for both groups and remained stable throughout the sessions.

By adding the average values for all the Presentation Actions we can get the total pTM value for each session. The PT displays at maximum one corrective feedback at the time, nonetheless it still keeps track and logs all Presentation Actions, meaning that multiple mistakes can be tracked simultaneously, therefore the total pTM value can be larger than 1. The total pTM average values for every session are listed in Table 4.4. In order to calculate the significance of these results we used a heteroscedastic t-test.

Table 4.3 pTM average for each training session

Session	1	2	3	4	5
pTM Voice					
Treatment	.15	.09	.12	.07	.07
Control	.22	.27	.22	.22	.21
pTM Posture					
Treatment	.1	.05	.07	.04	.02
Control	.35	.29	.27	.26	.27
pTM Gesture					
Treatment	.22	.16	.15	.15	.14
Control	.27	.41	.37	.36	.4
pTM Pauses					
Treatment	.04	.01	.01	.003	.01
Control	.07	.14	.35	0.04	.09
pTMP. Pauses					
Treatment	.002	.002	.002	.002	.002
Control	.003	.003	.003	.003	.002
pTM Grounded					
Treatment	.008	.005	.007	.004	.004
Control	.014	.006	.01	.03	.03

Table 4.4 Total pTM average for each training session

Training Session	Treatment Group total pTM	Control Group total pTM	t-test
1	$M = 0.51, SD = 0.48$	$M = 0.92, SD = 0.73$	$t(33) = 2.11, p < .05$
2	$M = 0.32, SD = 0.16$	$M = 1.11, SD = 0.95$	$t(20) = 3.71, p < .01$
3	$M = 0.35, SD = 0.28$	$M = 1.01, SD = 0.81$	$t(24) = 3.42, p < .01$
4	$M = 0.26, SD = 0.21$	$M = 0.92, SD = 0.75$	$t(22) = 3.78, p < .01$
5	$M = 0.25, SD = 0.19$	$M = 1.00, SD = 0.79$	$t(21) = 4.14, p < .01$

From the first training session, there were already significant differences between both groups. These differences increased during the sessions. The average total pTM for the treatment group decreased throughout the sessions, while staying considerably stable for the control group. These results indicate that the feedback of the PT has a positive influence on the user's performance, and helps users to continue improving with practice.

We used the pTM of the tracked Presentation Actions to measure the performance for the final elevator-pitch. The average of these values are shown in Table 5. These results show that for all tracked nonverbal aspects with the exception of phonetic pauses, the pTM average values for the treatment group were lower than for the control group. In the case of phonetic pauses the measured performance of the control group was slightly better.

Table 4.5 Total pTM averages for the final elevator pitch

	Treatment group	Control group
Volume pTM	0.182	0.217
Posture pTM	0.032	0.188
Gestures pTM	0.158	0.541
Cadence pTM	0.022	0.036
P. Pauses pTM	0.0028	0.0027
Grounded pTM	0.007	0.234

A heteroscedastic t-test was used to compare the difference of the total pTM values for both groups. There was a significant difference in the total pTM values for the treatment group ($M= 0.404$, $SD = 0.33$) and the total pTM values for the control group ($M= 1.01$, $SD = 1.05$) with $t(23)=2.46$, $p<.05$. This shows a significant difference in the performance among participants from the control and treatment group for their final elevator-pitch. This shows that the PT's feedback received during the training sessions had a positive influence on the participants' performance during the final elevator-pitch.

By comparing the total average pTM of this final elevator-pitch against the training sessions (see Figure 4.8), results show that the average pTM scores for the control group remained fluctuating in a range between 1.1 and 0.92 throughout the training sessions and the final elevator-pitch. This was in contrast to the case of the treatment group, where the pTM average values decreased throughout the sessions, and increased a bit for the final elevator-pitch. Nonetheless, this average value from the final elevator-pitch remained lower than the average pTM obtained from the first training sessions.

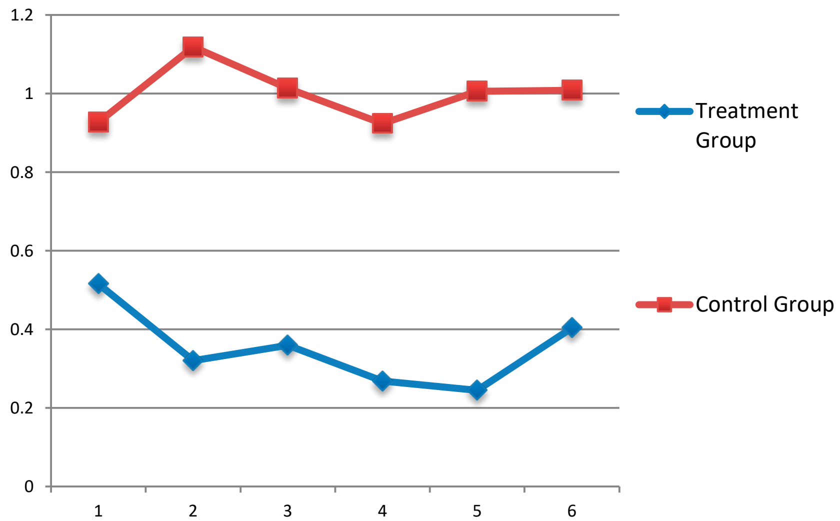

Figure 4.8 pTM average values for training sessions and final elevator pitch

Discussion

Background research showed the feasibility of using multimodal interfaces to support learning. Based on the knowledge obtained from this research we develop the PT. To go a step beyond a feasibility and usability study, and contribute to the state-of-the-art on multimodal systems for learning, in this study we explored the effects that the feedback of the PT has on learners practicing basic nonverbal public speaking skills. The effects can be arranged in two categories: learning perception and performance. When looking at the learning perception, participants show that the use of a tool such as the PT for learning compares relatively well in comparison to the educational practices occurring in traditional classroom settings. However, in contrast with our Hypothesis 1 the feedback of the PT was not the catalyzer for this result.

Results also indicate that the feedback of the PT has a positive influence in motivating learners to practice their speeches. This increase of motivation aligns to our Hypothesis 1 and can be explained by stating that the intervention performance feedback is an effective motivator for learners to achieve their goal (Jacobs, & Dempsey, 1993). The feedback of the PT helps learners to become aware of their performance, therefore motivates them to practice more.

When asking learners about their confidence on their elevator pitch skills, results indicate that the feedback of the PT has a positive influence in this confidence. This raise in confidence aligns with our Hypothesis 1, nonetheless differs with common practices in public speaking courses where in order to avoid hurting the confidence of the speaker, feedback is given using the sandwich technique (Docheff, 1990). In this sandwich technique weak points and mistakes made during the reviewed presentations are sandwiched in between the strengths of the speaker. This is in contrast with the PT that at its current stage only gives feedback about mistakes.

In self-regulated learning the strengths of involving learners as active participants in the assessment process is frequently discussed (Nicol, & Macfarlane-Dick, 2006). However, for the development of public speaking skills self-assessment has shown to be far less effective than the assessment coming from tutors (De Grez, Valcke, & Roozen, 2009; van Ginkel, Gulikers, Biemans, & Mulder, 2015b). This can partially be explained by the lack or reflection that learners have about their performance (van Ginkel et al., 2015b). Following the same line of reasoning the authors in (Higgins, Hartley, & Skelton, 2002) argument the relevance of external feedback in the development of academic skills. To explore whether the PT's feedback has a positive influence in the learners' self- assessment and self-awareness, in this study we compared the amount of mistakes that the participants reported to have make against the amount of mistakes tracked by the PT in the last elevator pitch. Results show a trend where the feedback of the PT helps learners to become better at identifying their own mistakes for all training areas on situations where the feedback of the PT is no longer present. This identification of own mistakes became particularly better for the trained areas that deal with the use of the body such as: body posture, hand gestures and staying grounded. By adding together the difference between perceived and identified mistakes from all the trained areas, results show significant differences between both groups, supporting our Hypothesis 1 stating that the feedback of the PT has a positive influence in the learner's self-awareness.

To test our Hypothesis 2 we analyzed the performance from training sessions showing learning was not a mere perception of the participants. Results reveal that the feedback of the PT has a positive influence in the performance of all the training areas except Phonetic Pauses. We have two reasons to explain the lack of influence regarding the use of Phonetic Pauses. The first reason has to do with the poor identification of them by the PT, on average only 20% of them are identified. Second reason deals with their timespan. Phonetic Pauses and their current feedback instruction have a duration that lasts only fractions of a second. We consider it difficult for users to correctly interpret and learn from these short time feedback instructions. To correct these types of short mistakes, research on different feedback strategies is suggested. For the rest of the training areas, which are better identified and have a longer timespan, the results of this study indicate that the feedback of the PT is effective during training sessions. This effectiveness is shown by the measured performance of the participants, where from the first session the treatment group already performed much better than the control group. Moreover results corroborate our Hypothesis 2 showing that the performances of the treatment group kept improving considerably throughout the sessions, while the performances of the control group remained stable.

In alignment with Hypothesis 2 results indicate that the PT's influence regarding the learners' performance goes beyond the training sessions. The logged performances of the final elevator pitches revealed how participants from the treatment group on average performed better on all trained areas with the exception of Phonetic Pauses, than participants from the control group. This implies that the feedback of the PT received during the training sessions, significantly improved the overall performances from the last elevator pitches. These last performances were better than the performances from the first training sessions, but not as good as the performances from the following ones. We consider that more training sessions using the PT are required in order for learners to perform in their final pitch as good as in the training sessions. This highlights one of the limitations of our study, which is that the long-term usage and resulting learning effects of the PT were not tested. As discussed before, results showed that the feedback of the PT has a positive influence in motivating learner's to continue practicing. However, we assume that the novelty of this feedback played an important role in the learner's reported motivation. Therefore, to keep learners interested some other motivational strategies should be implemented in the PT.

Some other limitations in our study regard the capabilities of the PT to assess the quality of an elevator pitch or presentation. These limitations of assessment start with the fact that the quality of a presentation or a pitch highly depends on its content and not only on its delivery, and the PT is only able to interpret part of its nonverbal delivery. The PT has also limitations on what it can interpret from the sensor data. For example, the current version of the PT cannot distinguish between gestures used for emphasis, iconic gestures, or waving hands without any purpose. Luckily not using enough gestures while giving a presentation is a common mistake in public speaking in comparison with waving the hands without a purpose, which would be also considered as a mistake, but so far we have not identified a single case of someone portraying this behavior. One more limitation that the PT has in assessing the quality of a presentation regards the common consideration of public speaking as a performing art. The creativity and capacity of the speaker to impress the audience play a big role in the quality of a presentation. Therefore, experience speakers might deliberately break "rules" in order to create the desired impact on the audience. This is not a big limitation since breaking a rule to deliberately create an impact requires a certain degree of self-awareness. Results from this study indicate that the PT is a tool that supports learners with the increase of self-awareness and development of basic nonverbal communication skills for public speaking, therefore helping them to reach a competence level where they could make an educated decision on when to deliberately break a specific rule.

Conclusions and Future Work

In this study we presented the Presentation Trainer, a system that with the use of sensors is capable to track, analyze and provide users with feedback that supports their learning in real-time. This learning support is achieved through a feedback mechanism that takes in consideration the learner's cognitive load required to perform the trained task while receiving, interpreting and adapting to the instructional feedback given by the system. In the scenario of using the PT as a supporting tool to practice for an elevator pitch, results of this study show that this type of automated feedback has a positive impact on:

- Increasing the learners' motivation to practice.
- Improving the ability of learners to identify their own mistakes in real time without the use of external feedback.
- Increasing the learners' confidence about their elevator pitch skills.
- Improving the learners' performance during and after the training sessions.

As discussed in the previous chapter, the PT has some limitations in terms of assessing the quality of a presentation. For future research it is important to investigate the relationship between the PT's assessment and human's assessment regarding the quality of a presentation. Moreover in order to improve the PT's assessment for future work we plan to investigate further how to assess the quality of a presentation based on nonverbal communication aspects, e.g. by conducting an expert study. The expected output of such a study is a more comprehensive and specific set of nonverbal communication rules for public speaking. Once implemented, this new and more comprehensive set of rules can improve the assessment capabilities of the PT. Another research gap that has not been addressed in this study, deals with the incorporation of a tool such as the PT in current educational practice and its long-term usage and learning effects. To address this gap we also plan to investigate its effects as a practice tool for learners following a public speaking course.

We consider wearable computing as an emerging trend with a lot of potential to influence learning. The current version of the PT makes use of a wristband to indicate learners about feedback events. One path of future research is to explore the usability and learning effects of this type of technologies in the contexts of the PT.

To conclude, the PT has shown to be a system able to interpret a small part of the user's natural nonverbal communication mechanism, and capable to communicate in real-time the results of this interpretation in such way that it has a positive impact on the learning process of the user. The PT has some limitations, as it cannot comprehend the content of a presentation and the provided feedback is simple and restricted to a limited set of basic rules. Thus, such a tool cannot substitute human tutors. Instead, the power of the tool relies on the ability to present opportunities for correct practice and rehearsal in cases where a human tutor is not available. This makes this multimodal sensor-based tool a valuable and effective addition to current educational practices.

Part III

Second Iteration

The previous iteration resulted in the creation of a version of the PT able to provide learners with the type of immediate feedback that can help them to improve their performance. Results form Chapter IV showed that according to measurements taken by the PT, learners receiving its feedback significantly improved the performance of their practiced elevator pitches. This improved machine-measured performance is not necessarily translated into better presentations. This second iteration aims to address this issue focusing in the two following aspects:

- The assessment and feedback model of the PT: is the assessment and feedback model of the PT in agreement with the view of experts?
- Training with the PT and human assessment: do learners who practice with the PT give better presentations according to their peers?

Chapter V

Presentation Trainer: What experts and computers can tell about your nonverbal communication

Despite initial positive results obtained from the first iteration, the PT still lacks grounding in a valid assessment model for nonverbal communication aspects in the context of presentations. This chapter describes a study where experts in public speaking were interviewed in order to come up with this valid model of assessment for the PT. These interviews also provided a formative evaluation of the PT. Experts expressed their views on how a tool such as the PT suits with common practices for teaching and learning public speaking skills. The results of the presented study identify 131 nonverbal communication practices that affect the quality of a presentation, and summarize experts' points of view regarding sensor-based public speaker instructors.

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Introduction

It was February 431 B.C. when Pericles gave his funeral speech and exhorted the people in Athens to live up to the standards set by the deceased (Thucydides). One hundred years later, inspired by Pericles's words, the Greek civilization became one of the most influential in human history. Today, more than 2000 years later, good public speakers still inspire people all over the world. The ability to present effectively is considered to be a core competence for educated professionals (Campbell, Mothersbaugh, Brammer, & Taylor, 2001; Hinton & Kramer, 1998; Parvis, 2001; Smith & Sodano, 2011; Morreale & Pearson, 2008). Policy makers in Europe have recognized this relevance and proposed to all higher education institutions to provide students with presentation skills qualifications (Joint Quality Initiative, 2004).

Research has shown that practice and feedback are fundamental aspects for the development and acquisition of public speaking skills (Van Ginkel et al., 2015a). However, opportunities to practice and receive feedback are limited, and graduates often lack the skills to speak in public (Chan, 2011) also due to missing experience and practice. Creating more opportunities to practice and receive the needed feedback through more human assistance is neither feasible nor affordable. Hence, the authors argue for technological solutions to face this problem. Sensor-based environments have become increasingly popular (Swan, 2012) and have shown to support learning through feedback in a great variety of learning scenarios (Schneider et al., 2015a). One of these scenarios is public speaking, where diverse sensor devices, such as depth cameras (Microsoft Kinect) and microphones have been used to develop multimodal research prototypes able to provide learners with feedback regarding their nonverbal communication (Barmaki, & Hughes, 2015; Batrinca et al., 2013; Damian, et al., 2015; Dermody & Sutherland, 2015; Schneider et al., 2015b).

One of these prototypes is the *Presentation Trainer* (PT). The PT supports the training and development of public speaking skills, by presenting the learner with real-time feedback regarding basic nonverbal communication aspects, such as the voice volume, posture, use of pauses and gestures. The study in Schneider et al. (2015b) contains a detailed description of the PT and shows that according to machine-based measurements the PT helped learners to significantly improve their performance. These results show the potential of the PT as a support tool for the development of presentation skills. Nonetheless, the goal of the PT is to ensure supporting learners in delivering better presentations to human audiences, in contrast of improving a machine-based score. Two important missing aspects are preventing the current version of the PT to achieve this goal. The first one is an externally validated model to assess influential nonverbal communication aspects for presentations. The second is a formative evaluation to identify how the use of the PT suits, complements and could enhance current training practices for the development of public speaking skills.

Currently the PT uses a rule-based model to assess the nonverbal communication aspects of presentations. This model is composed of a small set of behaviors that when identified are interpreted as mistakes by the PT. The set of recognized behaviors include: crossing arms, hiding hands, slouching, crossing legs, hopping from one foot to the other, not using enough pauses and gestures, and speaking at an incorrect voice volume. These behaviors can be identified in the vast literature regarding public speaking skills (e.g. Bjerregaard & Compton, 2011; Devito, 2014; Gallo, 2014). However, publications regarding these skills usually lack a formal validation of the ideas and concepts described by the authors. The study in Schreiber, Paul & Shibley (2012) faced this validation challenge and identified a set of validated rubrics to assess the quality of a presentation. However, the presented assessment regarding the nonverbal communication aspects of a presentation is quite limited and does not identify specific behaviors. It only mentions that the nonverbal communication should align with the message and should avoid being distractive. To contribute to the research of the PT and multimodal public speaker instructors in general, in this study we conducted semi-structured interviews with experts in public speaking. During the interviews we inquired about nonverbal behaviors that affect the quality of a presentation, and in addition, did an expert evaluation of the PT.

Method

Design and Sampling

In this study we conducted semi-structured interviews with 10 experts in public speaking. The group of experts consisted of three females and seven males. Eight of the experts have a Dutch nationality and two of them are British. The age of the experts ranged from 26 to 72 years old. Nine of the experts teach or have taught courses on oral communication skills. Three of them have an acting background; three of them have a personal coaching background; and one of them is a researcher on developing presentation skills.

Instruments and Procedure

We structured the interview in six different phases. The first two phases were designed to introduce the study to the experts and gather their personal information. The third phase of the interview consisted of general questions regarding the nonverbal communication during an oral presentation, such as its relevance and feedback methods used to improve it. The purpose of the fourth phase of the interview was to come up with a set of nonverbal communication behaviors that can be identified as ineffective or good practices during a presentation. The fifth phase of the interview inquired about the different phases of a presentation and the ineffective and good practices that can be typically identified on each phase. Finally, on the sixth phase of the interview the interviewer showed a live demonstration of the PT and asked the interviewee for impressions and opinions regarding the tool.

Data Collection

The interviews took place in May and June 2015. Nine of the experts were interviewed face-to-face and one of them was interviewed in a videoconference call. One interviewer conducted the 10 interviews, which lasted between 1 and 1.5 hours each. During the interviews an open atmosphere was created where expert and interviewer exchanged information and opinions about the subject. Each interview was audio recorded and then transcribed to a text document.

Data Analysis

To analyze information obtained from the interviews we first organized the transcribed data for each interview according to our own interview guideline, allowing us to individually analyze experts' ideas about: nonverbal communication in general and feedback techniques used to improve those skills, specific nonverbal behaviors that influence the quality of a presentation, particular nonverbal behaviors identified on the different phases of a presentation, and impressions regarding the PT.

We identified the different ideas and concepts from the interview through coding (Rubin & Rubin, 2011) using the NVivo 10[10] software tool. Then we counted the recurrences of the coded ideas and concepts among all the interviews in order to discover commonalities among the different experts.

By analyzing the coded ideas regarding the different phases of the presentation, it was possible to identify that there are some nonverbal behaviors that are unique for these phases and some others that are recurrent for all phases of the presentation. These recurrent behaviors were removed from the particular phases of the presentation and added to a list of nonverbal behaviors in general.

Validity and Reliability

We conducted an external validation (O'Connor & Gibson, 2003) in order to validate our coding process. To conduct this external validation out of the total 284 codes used in the interviews, we randomly selected 20 of these codes together with their corresponding extracted answers given by the experts. We asked eight external reviewers to connect the random codes from the list with the extracted answers from the experts, or suggest a new code in case they did not find a match.

The connections between the codes and the extracted answers conducted by the external reviewers in total had a match of 98% with ours. This high match is a good indicator regarding the reliability and validity of our coding process.

[10] http://www.qsrinternational.com/product

Results

Nonverbal communication ineffective and best practices

Regarding nonverbal communication in general, nine experts claimed it to be very important and one of them considered it as irrelevant. Our study identified four different reasons explaining this relevance. The principal reason supported by seven of the interviewees is that nonverbal communication is the mean to transmit the message. The second identified reason supported by five interviewees is that the nonverbal communication helps the speaker to bond and create trust with the audience. The third reason, asserted by three experts is that the likeability of the speaker highly depends on her nonverbal communication. Finally, two experts suggested that the nonverbal communication of the speaker supports the content of the presentation

When experts were asked about how to teach nonverbal communication skills, all experts replied of not being aware of a precise process on how to teach these skills. They replied that the teaching process usually adapts to the particular environment of the learners. Usually presentation skills are taught in a very intensive one-weekend course, or in once a week lessons that last for a whole semester. They can be taught in a group, or in one-on-one coaching sessions. What all experts pointed out is that practice and feedback are necessary to learn these skills.

Regarding the methods used to provide learners with feedback, five of the experts use a technique known as the feedback sandwich technique (Docheff, 1990). In this technique the teacher or peers first name one good aspect about the performance of the student, then an aspect for the student to improve, finishing by stating another good aspect about the student's performance. The main objective of this feedback technique is to help the student to make progress without damaging her self-confidence. One expert does not use the sandwich feedback technique but recommends framing the feedback as positive as possible for similar reasons. Three experts include self-, peer- and teacher-assessment to the their feedback. Pointing out that assessing a presentation is a subjective topic, without a right or wrong way to do it. Therefore, having different feedback sources helps to make the learning experience more comprehensive. One expert uses video recordings as a tool to give feedback. While reviewing the video after the presentation, students together with teachers can discuss it carefully. Two experts said to have used this feedback technique in the past but stopped using it because it is very time consuming and students usually feel uncomfortable while watching the recordings of their performances. One expert mimics the nonverbal communication of the students, and asks the students to reflect and discuss about it, helping them to become aware of the meaning of their own nonverbal communication.

The analysis of the interviews allowed us to identify 61 nonverbal behaviors that can be interpreted as ineffective communication practices and 70 behaviors that can be interpreted as good practices. These identified nonverbal behaviors can be grouped in seven sets of nonverbal communication aspect: posture, gestures, facial expressions, eye contact, use of stage, voice, and pauses.

Posture

Regarding the posture of the presenter, the most identified ineffective posture practice in the interviews, stated by seven experts, is giving the back to the audience, instead of facing them. Six of the experts mentioned that a common ineffective posture practice is dancing. This dancing behavior communicates to the audience that the presenter is nervous. So the presenter should avoid hopping from one foot to the other. Either from side to side what four of them also called as "Merengue", or back and forward what four of them called as "Salsa".

Eight of the experts mentioned the importance of having a posture where the presenter can feel grounded in order to communicate the message with confidence. They mentioned that the feet of the presenter should be between shoulder and waist width firmly on the ground, in order to become grounded. Three experts commented that it could be ok to move and change posture from time to time, as long as the presenter always returns to this grounded posture after some sentences. Most experts also stated the importance of standing erect in order to display confidence. Keeping the shoulders back and relaxed, the chin up, and the neck back were the behaviors that the experts recommended in order to achieve this erect posture. Most experts also recommended standing with an open posture facing the audience as much as possible in order to transmit that the presenter is communicating with the audience. The list displaying all the identified ineffective and good practices identified for posture is displayed in Appendix C.I.

Gestures

Seven of the experts stated that the biggest problem with gestures during a presentation is not using them. As stated by one of them: "There are no rules for the gestures, they have to be your own, but they have to be there".

Half of the experts mentioned that gestures during a presentation should be bigger than usual face-to-face communication as explained by one of them: "*One has to understand that with gestures and everything, everything on stage should be a bit exaggerated, because it is an abnormal distance for communication. Bigger, slower exaggerated gestures are more useful, and more clear for the audience"*. Half of the experts commented that gestures should be used deliberately. They can be used for enumeration e.g. "*When saying first, second, third also use your hands*". Gestures are useful to emphasize or stress important points during the presentation. They help the presenter to paint the picture in the audience mind e.g. "*While mentioning the whole world use big open arms gestures, it gives a physical and mental reflection of what you are doing".* Half of the experts recommended using a gesture and then return to your default or reset posture for presenting. Four of them reminded that gestures are not universal and that they can be interpreted in many different ways, thus recommended to always vocalize them in order to avoid misinterpretation and confusion. The full list of the identified ineffective and good practices regarding the use of gestures is displayed in Appendix C.II.

Facial Expressions

Considering facial expressions, nine experts stated that presenters should avoid having a blank face throughout the whole presentation. As one of them said: "*You should have an alive facial expression. Smile from time to time even when it is a very serious subject. It is good to see that the presenter is human and not trying desperately to be a professional scientific presenter. Because that is not accessible and the audience loses the attention".* As good practices for facial expressions eight experts said that as a general rule of thumb the presenter should smile from time to time during a presentation. Seven of them gave a warning reminding that the facial expression should be congruent with the content. As one of the experts said: "*You won't smile if you are talking about how the people in South Africa could not get their medicines*". The full list of the identified ineffective and good practices for facial expression is displayed in Appendix C.III.

Eye Contact

Eye contact is another important nonverbal aspect during a presentation. Eight experts identified that one problem that presenters have regarding eye contact is avoiding it. Also eight experts commented about the common ineffective practice of having fixed eye contact with someone in the audience while ignoring the rest.

Ten of the experts commented that a presenter should screen the audience and give as much of eye contact as possible. As one of the experts said: "*Look to your bread, the audience gives you the money, look at them. The trick is to more or less maintain your eye contact a bit behind the center of the audience in the center for a lot of time, but of course keep scanning everybody. And it is ok to directly talk to one person, and then to another."* All the ineffective and good practices regarding eye contact are displayed in Appendix C.IV.

Use of Stage

"*Using the stage with awareness is very powerful and useful, but one needs to know why they are walking around the stage".* Regarding the use of the stage the experts pointed out two ineffective practices. Six of the experts considered standing still behind the computer screen, desk or lectern as a behavior that should be avoided throughout a presentation. Four experts said that moving from one side of the stage to the other without a purpose should also be avoided.

In terms of good practices regarding the use of the stage, four experts noted that the presenter should stand in a place where the audience can see her. Five experts said that moving through the stage with purpose is a very good practice for presenting. One expert recommended to move through the stage according to the particular section of the presentation: "*Support your physical position with the section of the presentation. Move back if you want to create physical distance, when it becomes more theoretical*". Other expert recommended the following: "*Move left and right to communicate time or structure, and back and forward for intensity or intimacy*". The list of identified ineffective and good practices regarding the use of stage is displayed in Appendix C.V.

Voice

Eight experts stated that the biggest problem regarding the use of voice was that so many presenters just talk out-loud instead of speaking to the audience. Eight experts also mentioned that a big problem is to focus only on the content of the presentation and not on how to communicate it to the audience. Half of the experts mentioned that one should avoid filler sounds such as hmms, ahms, and etc. as much as possible, since they are distracting and communicate hesitation.

According to seven of the experts one of the most relevant uses of voice during a presentation is to speak to the audience. As one of the experts mentioned: "*Voice should be projected to the audience, you must speak to them*". The full list of identified ineffective and good practices regarding the use of voice is displayed on Appendix C.VI.

Pauses

"*When people become uncertain on the stage, they have the tendency to go faster, because they think the faster I am the sooner it will be over. They put themselves into a drive and do not pause. It never ever works when you are uncertain slow down, pause*". All experts stated on the interviews that the correct use of pauses is crucial during a presentation.

Six experts recommended pausing for a long period of time after telling something important and after asking any type of question. Half of them stated the importance of having a big pause before introducing a new topic. The full list of identified ineffective and good practices regarding the use of pauses is shown in Appendix C.VII.

Phases of a Presentation

The interviews allowed us to identify six phases in a presentation with particular non-verbal practices. These stages are shown in Table 5.1.

Table 5.1 Phases in a Presentation

Phases of a Presentation	# of experts identifying the phase
Walking to Stage	4
Settle in Time	10
Introduction	5
Middle	10
Conclusion	8
Questions and Answers	4

The first identified phase of a presentation is walking to the stage. As one expert stated: "*A common mistake while walking to the stage is trying to ignore that the presentation already started*". As good practices for walking to the stage, three experts recommended to walk slow and confident while giving eye contact to the audience.

As a second phase experts identified a settle in time. For this phase all experts agree that one should take their time to settle in before saying the first words. During this phase experts recommend to stand still with both feet firmly on the ground, calm down, take some deep breaths, and then start. All the particularly identified ineffective and good practices for these two phases are displayed in Appendix C.VIII and C.IX.

The following identified phase of the presentation is the introduction. The only particular ineffective communication practice for the introduction stated by one of the experts is starting to talk with a high pitch. As good for good practices experts explained that this phase has to be very intense, energetic but at the same time in a slow pace. As one of the experts passionately stated: "*If an airplane needs to take off, it needs a take off time. You cannot afford that take off time in a presentation; you have to be flying when you start, and you practice that. You need to have attention with yourself, attention with the audience, and dare to start in a different way. Ask yourself: How can I draw the audience to my story? You need stages of pauses especially at the beginning to draw the audience in; they have no clue what you are going to say. And you do not know where their minds are at the moment. You need to take your time to draw them in. High energy and low pace understanding that it is the first time they hear the story*". The full list of particular identified ineffective and good practices for the introduction of a presentation are displayed in Appendix C.X.

Advancing through a presentation the following phase is the Middle. Seven experts stated that the biggest problem on this phase is that the speech becomes monotonous, as one of the experts stated: "*This is the moment when the autopilot takes over, it becomes monotonous, same cadence all time, I push start and the robot is engaged.*"

Regarding the good practices for the middle of a presentation eight of the experts recommended changing dynamics during this phase. Experts gave some examples on how it is possible to change the dynamics of a presentation but explicitly stated that there is not one right way to do it. Some of these examples are to become theatrical for few seconds, move on the stage with purpose, change voice according to the subphase of the presentation, etc. One of them suggested to move to the back of the stage and speak very clear and slow when talking about something theoretical; then come close to the audience and talk at a normal speed when telling an anecdote. The full list of ineffective and good practices for the middle of a presentation is displayed in Appendix C.XI.

The next phase of a presentation is the Conclusion. Six experts said that a common ineffective practice is not ending the conclusion with a full stop, instead the presenter continues speaking and murmuring while waiting for the reaction of the audience. Five experts considered an ineffective practice when the presenter does not signify that the conclusion is coming and it appears too sudden.

Regarding good practices, eight experts suggested taking a couple of breaths and staying quiet for a while before giving the conclusion of the presentation. Six of them stated that the conclusion should be spoken slowly and clearly. Appendix C.XII displays a full list of the particular identified ineffective and good practices for the conclusion.

The final phase identified is Questions & Answers. The most common stated ineffective practice is to focus the attention only on the person asking the question. Therefore four experts recommended to identify and acknowledge the person asking the question, and then give the answer to the whole audience. The particular identified ineffective and good practices for Questions & Answers are displayed in Appendix C.XII

Formative evaluation of the Presentation Trainer

We organized the impressions of the experts regarding the PT in four different categories: Good points, limitations, possible improvements, and practical learning scenarios. The PT demonstration positively impressed all experts. Figure 5.1 summarizes in a word-cloud the experts' reactions.

Figure 5.1 Experts' impressions regarding the *Presentation Trainer.*

Besides the generally positive impressions regarding the *PT*, experts also pointed out some limitations (see Table 5.2). The biggest limitation stated by all of the experts is that there is not a right way to do a presentation; therefore a machine cannot really assess a presentation. Sometimes a presenter might deliberately break a rule and that does not mean that the performance went wrong. As some expert said: "*There is a risk of interventions not always making sense*". Another expert commented: "*Every person is different and what works for someone might not work for the other. Without the teacher I found it very difficult. In general you can't put rules.*" Following this line of argumentation, seven experts stated that the PT cannot be used as a substitution for a human tutor. Moreover, half of the experts remarked that nonverbal communication is tightly connected with content. Without understanding the content is impossible to make a right assessment about the nonverbal communication.

Table 5.2 Limitations regarding the PT according to experts.

Limitations	# Of Experts comments
No right way to do presentations	10
It cannot substitute a human tutor	7
No connection with content	5
Important to have real public	2
Kinect is not so accessible	2

During the interviews experts were keen on suggesting improvements for the PT. The list of the suggested improvements is displayed on Table 5.3. Since there is not a right way to do a presentation, eight of the experts suggested that the Presentation Trainer should shift focus and become a tool to develop awareness of nonverbal communication, instead of correcting it. To support this development of awareness, experts suggested improving the PT with the capacity to ask questions, which allow the user to reflect about her performance. One expert said: "*You could use it as if it was curious audience asking you why you did certain things, instead of a perfect instructor*". Continuing with the paradigm of creating a tool to raise awareness rather than a tool to correct behavior, three of the experts suggested switching the interventions from corrections to warnings letting the users decide whether their behavior was correct or wrong. Two experts proposed the PT to have configurable feedback rules where the teacher or user can set the type of behaviors that should be displayed and avoided for the specific type of presentation.

Four experts commented about adding a timeline at the end showing an overview of the presentation. One of them suggested that this overview could be sent to the teacher, helping the teacher to know what type of exercises and feedback to give to the student in the following lessons. Four of them also commented about the inclusion of videos showing how certain behaviors could be displayed during a presentation.

Table 5.3 Improvements for the PT according to experts.

Improvements	# Of Experts comments
Develop awareness	8
Presentation Trainer asking questions	5
Timeline at the end	4
Inclusion of training videos	4
Warnings instead of corrections	3
Exercises to practice one skill at the time	2
Configuration of the feedback rules	2
Configuration of the frequency of feedback	1
Patent	1
Levels of difficulty	1

Discussion

General nonverbal communication behaviors

The opinion of the experts regarding the relevance of the nonverbal communication for public speaking aligns with the information found in previous studies (Quianthy & Hefferin, 1999; Van Ginkel et al., 2015), stating that the nonverbal communication is a very important aspect in presentations. More important, however, the interviews with the experts allowed us to identify a substantial set of nonverbal behaviors that affect the quality of a presentation, making it possible to separate these behaviors into ineffective and good practices. It is important to note that while asking for these behaviors most experts continuously remarked that what they told is based on personal opinions and that one should not take these opinions as laws, since all nonverbal behaviors can be considered correct as long as they align with the message that the presenter wants to transmit. Though, in the whole set of identified behaviors we found many agreements and no contradictions among the experts' opinions. Moreover, the behaviors identified in this study show an alignment with the vocal expression and nonverbal behavior items from the validated oral presentation rubrics presented in Schreiber et al. 2012. This overall agreement aligns with the purpose of the PT, which aims to support the development of basic skills. It does not aim to train professionals to learn and create their individual presentation style.

Technical nonverbal communication behaviors

This study was conducted in the context of improving the PT; therefore it is relevant to analyze the feasibility of implementing computerized mechanisms to recognize the identified behaviors. Regarding the set of postures identified postures, it is possible to recognize them using depth cameras such as the Microsoft Kinect sensor (Le, Nguyen & Nguyen, 2013; Xiao, Mengyin, Yi, & Ningyi, 2012). This type of cameras have also been used to recognize predefined gestures (Li, 2012; Patsadu, Nukoolkit, & Watanapa, 2012; Ren, Yuan, Meng, & Zhang, 2013).

Some of the gestures practices mentioned by the experts, e.g. "waving both arms above the shoulders", "crossing arms", etc. are predefined, i.e., can be described with clear spatial constraints, therefore techniques to recognize these predefined gestures can be used. However, practices such as "gestures bigger than usual", "delivered gestures", etc. are not predefined, hence the amount of gestures that fall in this category is infinite and identifying them is still an open challenge.

"Vocalized gestures" can be identified through a multimodal. This approach requires input from microphones and depth cameras in order to identify whether a gesture is performed while the speaker is talking. By applying speech recognition techniques (Rabiner, & Juang, 1993; Graves, Mohamed, & Hinton, 2013) in combination with gesture recognition techniques it is possible to programmatically identify cases such as "Gestures for enumeration and sequences". This is by identifying predefined words such as "first", "second", etc., while the speaker is doing a corresponding gesture.

The automatic recognition of facial expressions is feasible as shown in the study of Bahreini, Nadolski and Westera, (2014). There are several techniques that can be used for eye tracking (Chennamma, & Yuan, 2013) that could be used for recognizing eye contact.

Regarding the voice behaviors identified by experts, there are existing techniques that can be used to recognize behaviors dealing with voice volume (Schneider et al. 2015b), voice pitch (Ghahremani, BabaAli, Povey, Riedhammer, Trmal, & Khudanpur, 2014) filler sounds (Prylipko, Egorow, Siegert, & Wendemuth, 2014), and voice emotion (Bahreini et al., 2014). Recognizing behaviors such as "talking out loud to yourself" instead of "speaking to the audience" and "stressing important words" remain currently an unsolved challenge.

The volume values captured by a microphone can be used to recognize pauses (Batrinca et al., 2013; Schneider et al., 2015b). Just by timely measuring the length of a pause, it is possible to differentiate between long and short pauses. However, experts did express not to know the length of short and long pauses, since they have always assessed these lengths intuitively without ever measuring them. Some solution to retrieve the lengths of shorts and long pauses is by timely measuring the pauses in recorded presentations (Schneider, Börner, Van Rosmalen, & Specht 2015c). Automatically assessing the precise moment to deliver a short or long pause is currently an unsolved challenge. In order to correctly recognize these correct moments computers have to understand the content of the presentation, something that currently is not feasible.

Formative expert evaluation of the PT

The formative evaluation of the PT made us to reconsider the type of feedback given by the PT, and helped us to identify how tools such as the PT can enhance current practices for learning public speaking skills. Regarding the feedback of the PT, before this study the feedback of the PT was designed to teach learners how to present correctly. Nevertheless, experts recurrently remarked that there is no right way to do a presentation; therefore instead of being a corrective tool, experts suggested to design the PT as a tool to support learners with the development of awareness. To raise awareness some experts recommended the use of questions and warnings as feedback instead of corrective instructions.

In terms of the enhancement of current practices for learning public speaking skills, experts stated that students in public speaking would benefit by using a tool such as the PT. In the case of students following a public speaking course, teachers could give homework asking students to practice certain skills using the PT. In the case of seminars and intensive public speaking workshops, attendees could take the PT home, use it to prepare for future presentations and get reminded of the lessons learned during the intensive training sessions.

Finally, experts claimed that the PT cannot substitute a human tutor. We partially agree with this claim, because in a presentation the verbal and nonverbal communication are tightly coupled. Currently it is not feasible for computers to make sense of the content of a presentation and analyze both forms of communication simultaneously. Thus in terms of the quality of assessment and feedback a tool such as the PT indeed is not able to compete against a qualified human tutor. However, we consider that tools such as the PT can still be used as tutors and support learners in the learning scenarios where human tutors are not available, e.g., in online courses and in informal learning situations.

Conclusions

The interviews conducted in this study allowed us to obtain crucial information for the improvement and further research on the PT and multimodal public speaking instructors in general. Even though generally speaking there is no "right" way to do a presentation, in this study we identified a wide agreement on good and ineffective nonverbal communication practices for public speaking. In total we identified a set of 61 ineffective practices and 70 good practices that can be taught to novice students in public speaking, which is the target group of the PT. Many of these practices can be recognized through the use of already existing computational techniques, making it possible to significantly expand the current rule-based model of assessment of the PT. Thus ensuring that practicing with PT will support learners in becoming better presenters.

The formative evaluation conducted in this study helped to shift the focus of the PT's feedback. As experts suggested future versions of the PT should include a feedback designed to raise the learner's awareness instead of just correcting them. This evaluation also pointed out how current practices for learning public speaking skills can be enhanced by tools such as the PT by presenting learners with opportunities to practice and rehearse the lessons learned in classrooms or seminars.

To continue with the improvement of the PT, the plan is to conduct a feasibility study regarding the implementation of the new assessment model of the PT together with the improvements suggested by the experts. The further step is to implement the identified improvements of the PT based on its feasibility and relevance.

As shown with Pericles funeral oration memorable presentations can lead to giant leaps for mankind. Becoming a great public speaker able to give memorable presentations is a complex task. Mastering the behaviors identified in this study is just one small step in becoming a great public speaker. Current technologies such as the PT present learners with the opportunities to become aware and master these behaviors.

Chapter VI

Enhancing public speaking skills - an evaluation of the Presentation Trainer 1in the wild

As shown in the results of Chapter IV the PT revealed promising empirical results in laboratory conditions, showing that by practicing with it learners can significantly improve their machine-based measured performance. This chapter reports on a study exploring the use of the PT in a classroom. The study has three main objectives. The first objective is to investigate whether the observed benefits of using the PT in a control laboratory condition hold in a classroom. The second objective is to explore whether training with the PT also leads to better performances according to a human audience. Finally the third objective explores whether the feedback of the PT can contribute to the creation of more comprehensive learning scenarios for public speaking. The results of this study help to understand the challenges and implications of testing such a system in a real-world learning setting, show that the feedback of the PT adds to the feedback from peers and tutors, and notably, results show that practicing with the PT helps learners to give better presentations according to human audiences.

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Introduction

Experiencing a great presenter delivering a novel idea is an inspiring event. Therefore, at least for the last 2500 years humans have been studying the art of the oratory (DeCaro, 2011). Currently the ability to present effectively is considered to be a core competence for educated professionals (Parvis, 2001; Campell et al., 2001; Hinton & Kramer, 1998; Smith, & Sodano, 2011). This relevance in learning how to communicate effectively is reinforced by the thought that ideas are the currency of the twenty first century (Gallo, 2014). Research on how to develop public speaking skills is a topic that has already been extensively studied. One of the conclusions to be drawn out of these studies is that practice and feedback are key aspects for the development of these skills (van Ginkel et al., 2015a). Whereas it is possible to attend different courses and seminars on public speaking, opportunities to practice and receive feedback from tutors or peers under realistic conditions are limited.

Sensors have lately become increasingly popular (Swan, 2012), showing to be a technology with great potential to enhance learning, by providing users with feedback in scenarios where human feedback is not available or to give access to data sources to enhance learning (Schneider et al., 2015a). This has led to the development and research of new sensory technologies designed to support users with the development of their public skills (Barmaki, & Hughes, 2015; Damian et al., 2015; Dermody, & Sutherland, 2015; Schneider, Börner, van Rosmalen, & Specht, 2015c). These technologies have not been widespread yet, and so far their impact has not been tested outside from controlled laboratory conditions. One of these technologies is the *Presentation Trainer* (PT), a multimodal tool designed to support the development of basic public speaking skills, by creating opportunities for learners to practice their presentations while receiving feedback (Schneider et al., 2015a). This paper describes a field study where we took the PT outside of the laboratory and tested it in a classroom. The paper discusses the implications of using such a system in the wild, and identifies which of the findings in a lab setting (Schneider et al., 2015a) also hold in the real world.

Background Work

Educational interventions such as feedback are needed to develop public speaking skills (Kerby, & Romine, 2009). Having a human tutor available to give feedback on these skills is neither always feasible nor affordable. Therefore, technological interventions designed to provide this feedback are desirable. Public speaking skills require from presenters a coherent use of their verbal and nonverbal channels. Timely measurement of these multimodal performances with an acceptable accuracy is challenging. However, in recent years driven by the rising availability of sensors, research on multimodal learning applications designed to support the development of public speaking skills has been undertaken.

During a presentation, the presenters communicate their messages using their voice together with their full body language, e.g., body posture, use of stage, eye contact, facial expressions, hand gestures, etc. Multimodal learning applications supporting the development of public speaking skills (Barmaki, & Hughes, 2015; Damian et al., 2015; Dermody, & Sutherland, 2015; Schneider et al., 2015b; Schneider et al., 2015c; Wörtwein, Chollet, Schauerte, Morency, Stiefelhagen, & Scherer, 2015) generally use a depth sensor such as the Microsoft Kinect[11] in order to capture the body language of the user, and microphone devices to capture the user's voice.

Studies on applications designed to support public speaking skills have been exploring effective strategies to provide feedback to users. In (Damian et al., 2015;) feedback indicating whether the energy, body posture and speech rate is correct or not, is displayed on a Google Glass[12]. Another feedback strategy employed in (Barmaki, & Hughes, 2015; Wörtwein et al., 2015] is the use of a virtual audience. Members of the virtual audience change postures and behaviors depending on the nonverbal communication of the user. Besides the display of the virtual audience the prototype in (Barmaki, & Hughes, 2015) also provides the user with direct visual indications regarding her own body posture. The applications in (Dermody, & Sutherland, 2015; Schneider et al., 2015b) provide the user with a dashboard interface that displays a mirrored image of the user together with modules indicating the use of nonverbal communication aspects such as use of gestures, voice, etc. In line with that, the feedback interface of the PT shows a mirror image of the user and displays at maximum one instruction to the user regarding her nonverbal communication at a given time (see Figure 6.1). This instruction is communicated to the user through a visual and a haptic channel (Schneider et al., 2015 c).

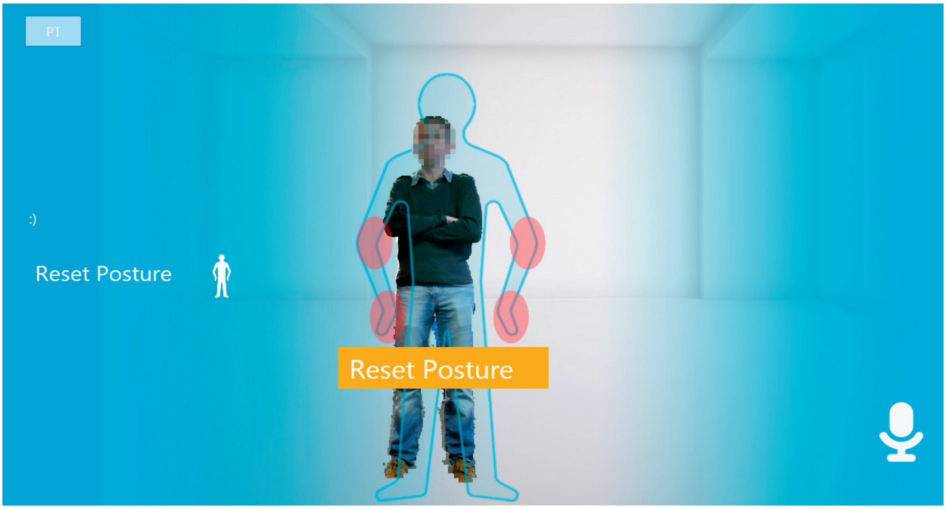

Figure 6.1 PT telling the user to correct the posture.

The impact of this type of applications on learners has also been studied, showing positive results in laboratory conditions. In the study of (Barmaki, & Hughes, 2015)

[11] https://dev.windows.com/en-us/kinect/hardware
[12] https://www.google.com/glass/start/

the feedback of the system, regarding the closeness or openness of the learner's body posture, helped learners to become more aware of their body posture. The impact of the PT's feedback on learners has also been studied in controlled setups. The study in (Schneider et al., 2015c) showed, through objective measures made by the system, that after five practice sessions receiving feedback from the PT learners on average reduced 75% of their nonverbal mistakes.

Purpose

In this study we tested the PT in a classroom setting following an exploratory research approach (Shields, & Rangarajan, 2013), focusing on three main objectives:

Objective 1: The first objective of this study is to explore the implications of investigating the use of a tool such as the PT in a regular learning scenario outside of a laboratory setup.

Objective 2: Studies on multimodal learning applications for public speaking have shown promising results in laboratory conditions according to quantified and timely machine measurements (Barmaki, & Hughes, 2015; Schneider et al., 2015c). However, the purpose of a presentation is to transmit the desired message and provide the desired impact to a human audience, in contrast of improving a machine-based score. Studies showing evidence that an improved performance according to machine measurements is reflected in a better presentation according to a human audience are still missing. Therefore, the second objective of this study is to gain insights on how the improvements obtained by a learner using the PT to practice for a presentation relate to the impact that this trained presentation has on the audience. In other words, to what extent does an audience agree with the PT that a presentation improved.

Objective 3: A core competence for current professionals is having good public speaking skills (Parvis, 2001; Campell et al., 2001; Hinton & Kramer, 1998; Smith, & Sodano, 2011); therefore teaching these skills has become a common target for different courses. Feedback is a key aspect for learning and developing public speaking skills (van Ginkel et al., 2015a), therefore current courses in public speaking include well-established feedback practices to help learners with the development of these skills. The effectiveness of this feedback depends on various variables. One of these variables concerns the source where the feedback comes from. Feedback provided by a tutor in combination with feedback provided by peer students has proven to be more effective than feedback provided only by a human tutor (Mitchell, & Bakewell, 1995). The third objective of this study, researches the introduction of the PT to the already established practices for teaching public speaking skills, exploring whether its use and feedback contribute to the creation of more comprehensive learning scenarios for students.

Method

Study Context

We conducted this study in the setting of a course in entrepreneurship for master students in a university. In this course students were divided in two teams, where each team is represented as an entrepreneurial business. During the course the teams have to develop and present their project. Thus, the students of the course receive some presentation training guidance. The teams have to give a presentation about their projects twice, at the middle and at the end of the course. The middle term presentations are recorded and in following sessions these recordings are used to give feedback to the students regarding their presentation skills, both by tutors and peers.

Study procedure

This study was conducted some sessions after the students have already presented their project and received feedback. Nine participants, seven males and two females between the age of 24 and 28 years old took part in the study. A sketch of the study is shown in Figure 6.2. To prepare for the study, students got the homework to individually prepare a 60 to 120 seconds long pitch regarding their project. One week later the study was conducted during a two-hour session slot.

The study started with students individually presenting their pitch in front of their peers and course teachers. The objective of this first pitch was to obtain a baseline of the students' performance. Peers evaluated the pitch by filling in a presentation assessment questionnaire.

After presenting the pitch each student moved to another room for the practice sessions. Before the practice sessions, students received a small briefing regarding the PT's feedback. The purpose of this small briefing was to reduce the exploration time needed to understand the feedback given by the PT. After this short briefing time, participants were supposed to know how to correctly react to the feedback given by the PT. The practice sessions consisted delivering the pitch two consecutive times while receiving feedback from the PT. During the practice session students stood between 1.5 and 3m in front of the Microsoft Kinect sensor and a 13-inches display laptop running the PT.

For the next phase of the study, the student returned to the classroom and presented the pitch once more to their peers. The objective of this second pitch was to explore the effects of the practice sessions. To observe these effects, peers evaluated this final presentation once more by filling in the presentation assessment questionnaire. The PT was also used to assess these pitches. However, due to a technical failure only the pitches given by the last three participants were assessed by the PT. After delivering this final pitch, students were asked to fill in a questionnaire regarding the experience of using the PT to practice.

Apparatus and Material

To evaluate the pitches done by the students, peers filled in a presentation assessment questionnaire. The questionnaire consists of eleven Likert-scaled items. The first seven items refer to a general assessment of the presentation including: the overall quality of the presentation, delivery of the presentation, speaker knowledge about the topic, confidence of the speaker, enthusiasm of the speaker, understandability of the pitch, and fun factor of the pitch. The last four items consisted of some of the specific non-verbal behaviors that can be trained using the PT: posture, use of gestures, voice quality, and use of pauses.

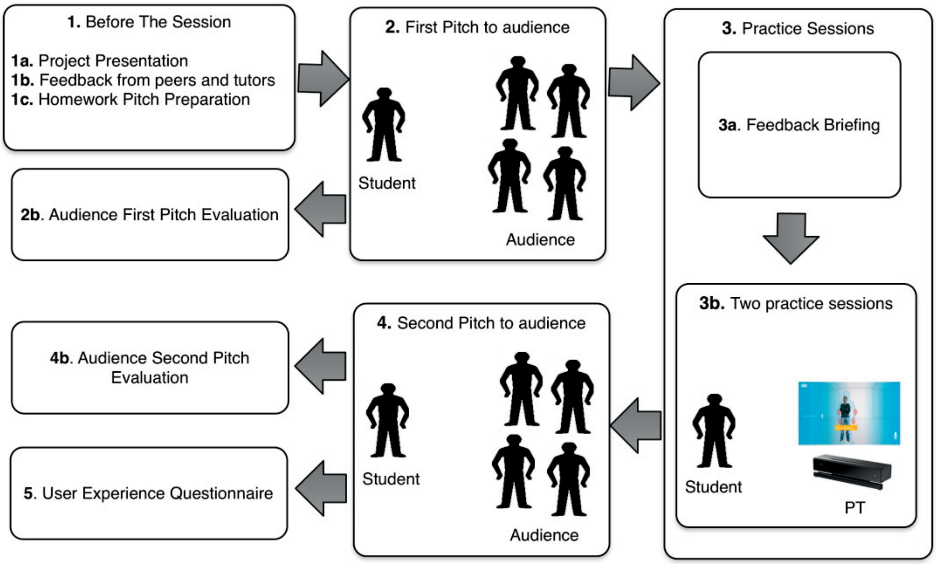

Figure 6.2 Study Procedure

To practice for the second presentation of the pitch students used the current version of the PT. This version of the PT uses the immediate feedback mechanism described in (Schneider et al., 2015c), providing users with the maximum of one corrective feedback at the time regarding their body posture, use of gestures, voice volume, phonetic pauses or filler sounds, use of pauses, and facial expressions (45 seconds without smiling). The PT logs all the recognizable behaviors (mistakes and good practices) as events. It displays these events at the end of each practice the session a timeline (see Figure 6.3) allowing learners to get an overall picture of their performance. These logs are stored into files that can later be used for data analysis.

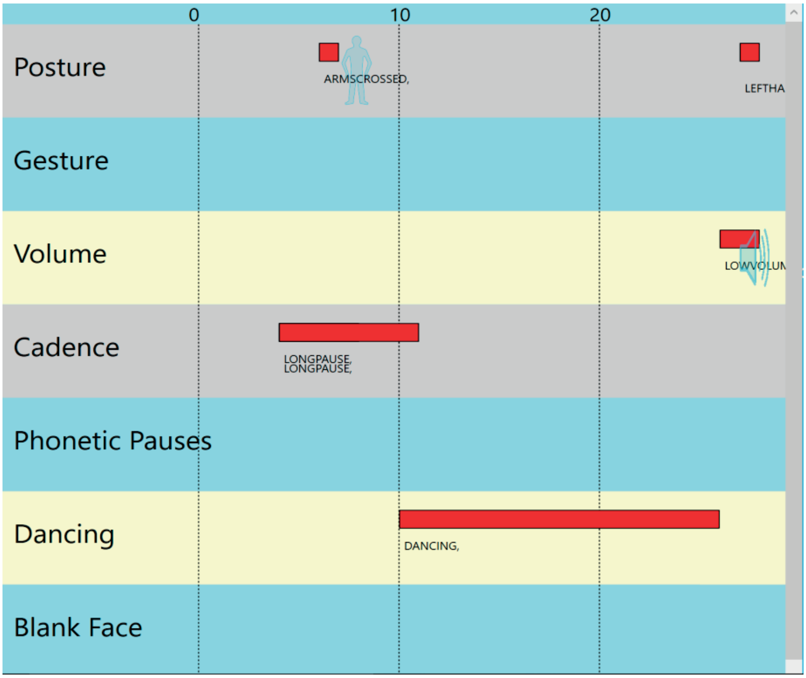

Figure 6.3 Timeline displaying all tracked events, showed to the user after the presentation.

A user experience questionnaire was used to capture the impressions of the students regarding the use of the PT. This questionnaire consists of seven items in total, five Likert-scale items and two open questions. The purpose of this questionnaire was to inquire the learning perception, usefulness of the system, and comparison between human assessment and system assessment.

Results

The peer evaluation of the first pitches is shown in Figure 6.4. Regarding the general aspects of the pitch, the item with the best score was the knowledge about the topic displayed by the presenter with an average score of 3.76 and the item with the lowest score was the entertaining factor of the pitch with an average score of 3.1. The non-verbal communication behavior with the highest score was the voice quality of the presenter with an average score of 3.73 and the behavior with the lowest score was the proper use of pauses during the pitch with an average score of 3.21.

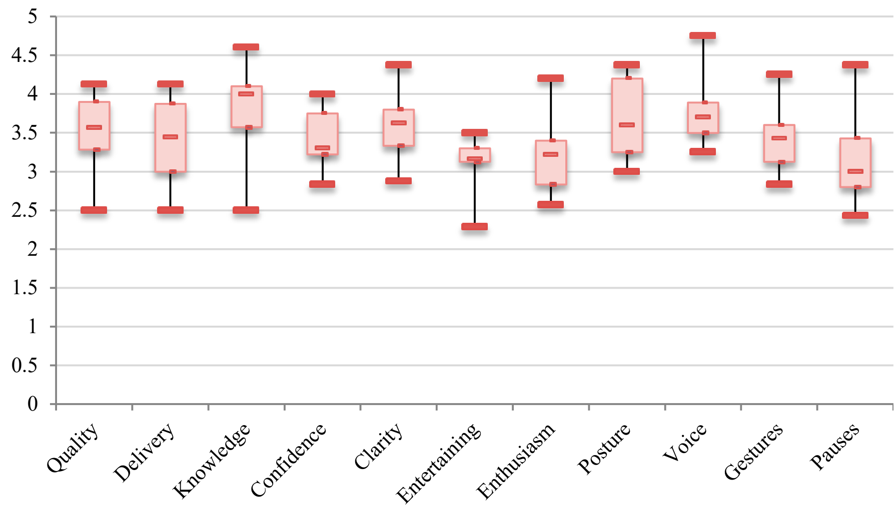

Figure 6.4 Evaluation scores of the first pitches.

After giving the first pitch, students practiced it two times using the PT. We analyzed these practice sessions using the logged files created by the PT. To evaluate the impact of each of the identified behaviors captured by the PT, we used the percentage of time that this behavior was displayed during the training session (pTM). The pTM value for each behavior has a range from 0 to 1, where 0 indicates that the behavior was not displayed at all and 1 indicates that the behavior was identified throughout the whole presentation. The average pTM values for all the tracked behaviors are displayed in Table 6.1. Results indicate that participants on average during the second practice session show an improvement in all trained aspects. The behavior that on average received the worst assessment for the first practice session was the use of gestures, followed by the voice volume and then posture. The pTM value for the other tracked behaviors was very low. In the second practice session voice volume received the worst assessment, followed by gestures and then posture. The area showing the biggest improvement was the use of gestures.

Table 6.1 pTM scores capture during the practice sessions. Mean and standard deviation.

	Posture pTM	Volume pTM	Pauses pTM	Blank F. pTM	Gestures pTM	Dancing pTM	Phonetic P. pTM	Total pTM
Session 1	0.132 (0.22)	0.179 (0.16)	0.040 (0.41)	0.083 (0.14)	0.217 (0.18)	0.026 (0.08)	0.020 (0.01)	**0.697** **(0.31)**
Session 2	0.078 (0.11)	0.167 (0.11)	0.010 (0.17)	0.019 (0.02)	0.123 (0.12)	0 (0)	0.017 (0.01)	**0.414** **(0.22)**
Mean Difference	0.054	0.012	0.030	0.064	0.094	0.026	0.004	**0.284**

The peer evaluation of the pitches presented after the practice sessions is shown in Figure 6.5. Regarding the general assessment of the pitches the item with the highest score was the knowledge about the topic displayed by the speaker with an average score of 3.96. The item with the lowest score having an average of 3.55 was the entertaining factor of the pitch. Regarding the nonverbal communication aspects, the one with the highest score was the voice quality of the presenter with and average of 4.14 and the correct use of pauses was the lowest with and average of 3.71.

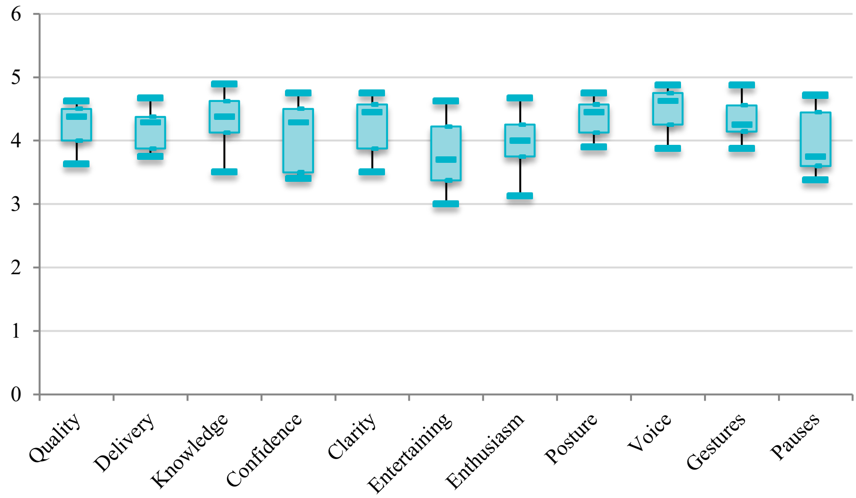

Figure 6.5 Evaluation scores of the second pitches.

To explore the relevance of having a tool designed to practice specifically the delivery of the pitch, we used Pearson's r to measure the correlation between the scores of the overall quality of the pitch (content + delivery) and the scores of its delivery. These measurements show a correlation of [r=0.94, n=18, p<0.01]. We also used Pearson's r on the scores of the pitches to measure the correlation between the behaviors that can be trained using the PT and the overall quality of the presentations (see Table 6.3). This with the objective to explore the relevance of training these behaviors. The behavior displaying the strongest correlation was the use of pauses, followed by posture, voice quality and use of gestures.

Table 6.2 Pearson's linear correlation between aspects that can be trained with the PT and overall quality of the pitch.

Aspect trained	Overall Quality
Posture	r=0.86, n=18, p<0.01
Voice	r=0.85, n=18, p<0.01
Gestures	r=0.76, n=18, p<0.01
Pauses	r=0.89, n=18, p<0.01

Figure 6.6 shows the comparison in the evaluations between the first and second pitches. These comparisons show and improvement in all evaluated items. The general quality of the pitches increased on a 21.94%. We calculated the significance of this difference using a t-test. The result of this t-test was t(14) = 3.6, p < .01. This indicates

that the improvement observed is statistically significant. Regarding the general aspects of a presentation the delivery of the pitch was the item displaying the biggest improvement showing an increment of 24.27%. The item showing the lowest improvement was the knowledge about the topic displayed by the presenter. This item had an improvement of only 14.37%.

By examining the improvements on the nonverbal communication behaviors, the area that displayed the biggest improvements was the use of gestures with an increment of 27.89%.

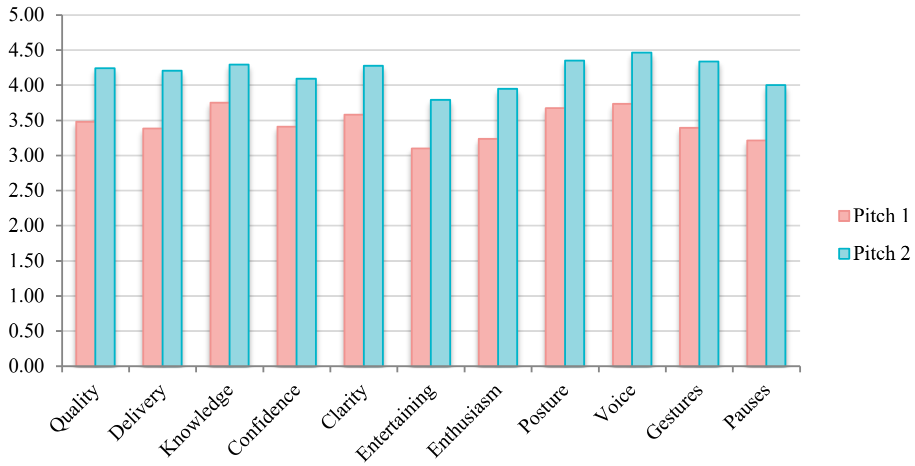

Figure 6.6 Comparison between first and second pitch

The PT's assessment the second pitch for the last three speakers is shown in Table 6.3[13]. Results from these tracked performances show that all of them had a total pTM value lower than 1.

Table 6.3 pTM values for the last three speakers on their final pitches.

Speaker #	Posture pTM	Volume pTM	Pauses pTM	Blank F. pTM	Gestures pTM	Dancing pTM	Phonetic P. pTM	Total pTM
7	0.160	0.088	0.054	0.104	0.000	0.000	0.026	0.427
8	0.148	0.063	0.153	0.000	0.000	0.000	0.026	0.390
9	0.142	0.105	0.112	0.243	0.000	0.015	0.039	0.656
Average	**0.150**	**0.085**	**0.106**	**0.115**	**0.000**	**0.005**	**0.030**	**0.491**

Results from the user experience questionnaire are listed in Table 6.4. These scores show that students would likely use the PT to prepare for future presentations. Results show that students perceived an increment of their nonverbal communication awareness. Students felt that the feedback of the PT is more useful as an addition rather than as a reinforcement of the feedback that peers and tutors can provide.

[13] 'A technical failure prevented data capture of the first six participants' (See section 4.2).

Table 6.4 Results from the user experience questionnaire. Mean and standard deviation.

Item	Likert-scale scores (1 Strongly disagree - 5 Strongly Agree)
My nonverbal communication awareness increased	3.89 (0.93)
I learned something while using the PT	3.67 (1.12)
I see myself using PT in the future	4.11 (0.78)
The PT reinforced the feedback of peers and tutor	3.56 (0.88)
The PT complements the feedback of peers and tutor	3.78 (0.83)

When asking students about the similarities between the PT's and the feedback received in previous sessions by tutors and peers all students mentioned the correct use of pauses while presenting. Two of them also mentioned the use of gestures. Four students mentioned that, previously, they received the feedback of not given enough eye contact to the audience by their tutors and peers and that this aspect is missing in the PT's feedback. Three students commented that receiving immediate feedback by the system makes it much more easy to identify and correct their behavior. One student mentioned that the PT gave feedback regarding the phonetic pauses while peers and tutors did not. One student mentioned a contradiction between the feedbacks regarding the use of voice. Peers and tutors in a previous presentation told the participant to speak louder, and during the training sessions the PT told the participant to speak softer.

Discussion

Studying the use of the PT outside of the laboratory in a real life formal learning scenario has several implications. In studies conducted in the lab, the setup of the experiment is carefully designed, allowing experimenters to have full control of variables such as time of each experimental session, location and instruments. This control allows the acquisition of reliable and replicable results. For this study we had to adapt our setup according to the restrictions of the ongoing course followed by the students. We encountered two main challenges while designing and conducting our study: time and location.

Regarding time, in previous laboratory studies participants had individual timeslots of sixty minutes, where they received all the briefing necessary and had five practice sessions with the PT. Moreover, experimenters had the chance to conduct their study with a large enough control and a treatment group, allowing them to assess significant results (Schneider et al., 2015c). For this study we had two hours to conduct the whole experiment without knowing beforehand the amount of students that would show up that day for the course. Therefore, we reduced the training sessions from five to three and adapted to only two training sessions during the flow of the experiment. The act of training with the PT is individual and designed to be performed in a quiet room where the learner can focus on the task. That forced us to use a separate room where one student could do the practice session while the others waited in the lecture room.

The room used for the practice sessions was not designed for the setup of the PT. The location of the power plugs, lighting conditions, place to position the Kinect and laptop screen running the PT were far from ideal. This problem of not having the ideal practice setup partially explains the difference between the average pTM values obtained in this study and the ones obtained in laboratory conditions (Schneider et al., 2015c). In lab conditions the average values from the first and second training sessions were 0.51 and 0.32 respectively, while in this study they were 0.69 and 0.41. Nevertheless, despite the differences the values did show a similar trend displaying similar improvements in a less than ideal setting.

Previous studies showed that using the PT to practice for presentations improves the performance of the learner according to the measurements tracked by the PT (Schneider et al., 2015c). The second objective of this study was to investigate whether using the PT to practice a presentation has also an influence in the way that the audiences perceives it. Results from this study showed that according to a human audience, all participants performed better in all aspects after having two practice sessions with the PT. The restricted time slot and restricted number of participants, did not allowed us to make use of a controlled and a treatment group. Therefore it is not possible to directly determine whether the improvements perceived by the audience are the results of practicing with the PT or just practicing. The results, however, revealed three key aspects suggesting the influence of the PT on this perceived improvement. The first key aspect is revealed by the assessed improvements regarding the general aspects of a presentation. The item showing the least improvement between the first and the second pitch is the knowledge that the presenter displayed regarding the topic. While on the other hand the item showing the biggest improvement was the delivery of the pitch. This aligns with the fact that the focus of the practice sessions using the PT was purely on the delivery of the pitch.

The second key aspect pointing out the influence of the PT has to do with the use of gestures. Use of gestures exhibited the biggest improvement from the first human assessed pitch to the second. This aligns with the computer assessment from the two practice sessions, where the aspect exhibiting the biggest improvements was also the use of gestures.

The third key aspect suggesting the influence of the PT is the PT's assessment of the three of the nine final pitches. In previous studies the average total pTM for presentations of people who did not practice with the PT was close to 1.0, in contrast with the results shown in this study where all the three measured final pitches had total pTM below 0.67. Unfortunately, as mentioned before, due to technical and logistical difficulties we were not able to assess all pitches using the PT.

For the third objective of this study we investigated whether the introduction of a tool such as the PT can contribute to the creation of more comprehensive learning scenarios for the acquisition of public speaking skills. Results from our study support this. As seen in the evaluations of the first pitch, the highest evaluated aspect was the knowledge of the topic displayed by the presenter. This gives us a hint that when preparing for a presentation or a pitch, a common practice is to focus efforts on preparing only its content. This practice does not seem optimal according to the strong correlation measured in this study between the overall quality of a pitch and the quality of its delivery. The results illustrate how by practicing the pitch two times using the PT, students significantly improved the overall quality of it. The students also reported benefits regarding their experience of using the PT to practice. They affirmed that the practice sessions helped them to learn something about public speaking and increase their nonverbal communication awareness. It is interesting to note that according to the students the feedback of the PT complements the feedback received by tutors and peers. Three students stated that the immediate feedback received by the PT helped them to exactly identify and correct their behavior. One more important aspect to note is that students expressed the intention to use the PT in the future.

This study showed some benefits of using of a tool such as the PT to support common practices for learning public speaking skills. However, the introduction of such a tool is still a challenge. The Microsoft Kinect is not a product owned by many students, and it is not feasible to provide each student with a Kinect in order to train some minutes for their presentations. However, Intel is already working in the miniaturization of depth cameras that can be integrated to laptop computers[14]. Therefore, in a medium term it will become more feasible for students to have access to tools such as the PT and use them for home practice. In the meantime the introduction for dedicated places to practice the delivery of presentations would be needed in order to introduce the support of these types of tools to the current practices for teaching and learning public speaking skills.

Conclusion and Future Work

The creation of multimodal learning technologies to support the development of public speaking skills has been driven in recent years by the advances and availability in sensor technologies. In laboratory settings some of these technologies have already started to show promising results. In this study we took one of these technologies, the *Presentation Trainer*, outside of the lab and conducted some tests with students following an entrepreneurship course as part of the course agenda. The main purpose of this study was to start the exploration of the support that these technologies can bring to a formal learning scenario.

Studying the use of the PT for a real classroom task revealed that location and time constrains interfere with the straightforward conduction of research. Due to location constrains it was not possible to set up the PT in ideal conditions for its use. Due to time constrains it was not possible to have the students follow all the expected training sessions, and we were not able to use the PT to measure all the first and second pitches presented to the audience. These constrains do not allow us to determine the causes for some of the obtained results in this study. However, results from this study align to a large extent with results obtained in the lab (Schneider et al., 2015c).

[14] http://www.intel.com/content/www/us/en/architecture-and-technology/realsense-overview.html

Regarding the support that the use of a tool such as the PT can bring to the established practices of teaching and learning public speaking skills, results from this study show the following:

- Students see themselves willingly using a tool such as the PT to practice for future presentations.
- Students find the feedback of the PT to be a good complement to the feedback that peers and tutors can give.
- Practicing with the PT leads to significant improvements in the overall quality of a presentation according to a human audience.

For future work we plan to show the results obtained in this study indicating the advantages of using the PT to coordinators of public speaking courses. This comes with a plan to deal with environmental constraints impeding the setup of PT and, hence, its use in the wild. Furthermore we plan to continue improving the PT. The purpose of the PT is to help humans give better presentation to humans. Hence, we plan to explore the relationship between human-based and machine-based assessment, and study how this information can later be used to provide learners with better feedback.

To conclude, there is still a lot of room for improvement for multimodal learning applications designed to support the development of public speaking skills. Introducing them to formal and non-formal educational scenarios still has some practical challenges. Though the application of the PT in a practical setting may not require equally strict conditions as in our research. In any case, studying the use of the PT in the wild has shown promising results regarding the support that such tools can bring to current practices for learning public speaking skills, indicating how courses on developing public speaking skills can be enhanced in the future.

Part IV

Third Iteration

Results from the two previous iterations show that practicing with the PT helps learners to improve their performance according to machine-based measurements and to give better presentations according to human audiences. This third iteration aims to continue with the improvement of the PT, exploring how sensor-based applications can be used to not only cognitively but also affectively support learners, and researching the introduction of sensor-based applications to oral communication courses in secondary schools.

Chapter VII

Do you know what your nonverbal behavior communicates? – Studying a self-reflection module for the Presentation Trainer.

Experts interviewed in Chapter V claimed that ultimately there is no such thing as the right way to do a presentation. They pointed out that it would be useful for tools such as the PT to present learners with the opportunity to become aware of their own non-verbal communication. Following this suggestion the PT was improved with a self-reflection module. This chapter presents a study consisting of user tests exploring the use of this module. Results from these tests showed that participants perceived that the self-reflection module helped them to reflect about their performance, and point out research paths to further investigating the influence of self-reflection in the learners' performance.

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Introduction

Instead of pledging for mercy after being accused from corrupting the minds of young people, Socrates in his public apology gave one of the most influential speeches of all time with the central message claiming that “the unexamined life is not worth living” (Plato, 1954). From asking people to examine their life, to influencing a whole country to send a man to the moon (Kennedy, 1962), public speeches have the power to shape human history. Currently educational researchers, teachers, employers and policy makers consider public speaking as a core competence for educated professionals (Parvis, 2001; Campbell et al., 2001; Hinton, & Kramer, 1998; Smith, & Sodano, 2011) and include it in the list of 21st century skills that help learners to function effectively at work as well as in their leisure time (Ananiadou, & Claro, 2009; Dede, 2007; Kalantzis, & Cope, 2012).

Practice and feedback are key aspects for the development of public speaking skills (van Ginkel et al., 2015a). Nevertheless, the opportunity for learners to get enough practice and feedback in current public speaking courses is limited, thus graduates often lack the skills to speak in public (Chan, 2011). Providing learners with the feedback needed through human assistance is neither a feasible nor a practical solution. Computerized systems with multimodal sensing capabilities have already been used to provide learners with feedback for numerous types of learning applications when human tutors are not available (Schneider et al., 2015a). These learning applications include the development of basic public speaking skills, where several presentation training applications have been developed and tested showing positive results in laboratory (Barmaki, & Hughes, 2015; Damian et al., 2015; Dermody, F., & Sutherland, 2015; Schneider, Börner, van Rosmalen, & Specht, 2016a) and classroom conditions (Schneider, Börner, van Rosmalen, & Specht, 2016b). One of these applications is the *Presentation Trainer* (PT), a multimodal tool that allows learners to practice their presentation skills while receiving basic feedback in real-time regarding their nonverbal communication (Schneider et al., 2016a). One limitation of the PT according to experts in the field of public speaking is that the PT provides learners only with corrective feedback when ultimately there are no strict rules for presenting to the public (Schneider, Börner, van Rosmalen, & Specht, 2017a). Therefore, experts suggested to expand the focus of the PT, making it a tool that allows learners to increase their level of awareness and help them to reflect on their performance (Schneider et al., 2017a).

To improve the PT, based on the expert evaluation, we developed a self-reflection module for the PT. The purpose of this paper is to report on the user tests conducted to explore the usage and impact of this self-reflection module.

Presentation Trainer

The Presentation Trainer is a multimodal tool designed to support the development of basic public speaking skills. It allows learners to practice their presentations while receiving feedback regarding their nonverbal communication. The PT uses the Microsoft

Kinect V2 sensor to capture the nonverbal communication of the learner. The learner can practice her speech while standing in front of the Kinect sensor and receiving immediate feedback from the PT. The reason for providing immediate feedback to the learner is that for aspects that can be corrected immediately such as the nonverbal communication, immediate feedback has proven to be more effective than delayed feedback (King et al., 2000). Another important aspect of the PT's feedback is that it provides the learner with a maximum of one corrective feedback instruction at a given time (see Figure 7.1). This because the display of multiple feedback instructions at a given time has shown to be too overwhelming for the learner (Schneider et al., 2015b). With the addition of the self-reflection module, a practice session with the PT consists of two phases. In phase one, the learner practices her presentation and receives immediate feedback through the real-time module. All data is captured and aggregated for use in the self-reflection module. In phase two, the learner is guided through the self-reflection module.

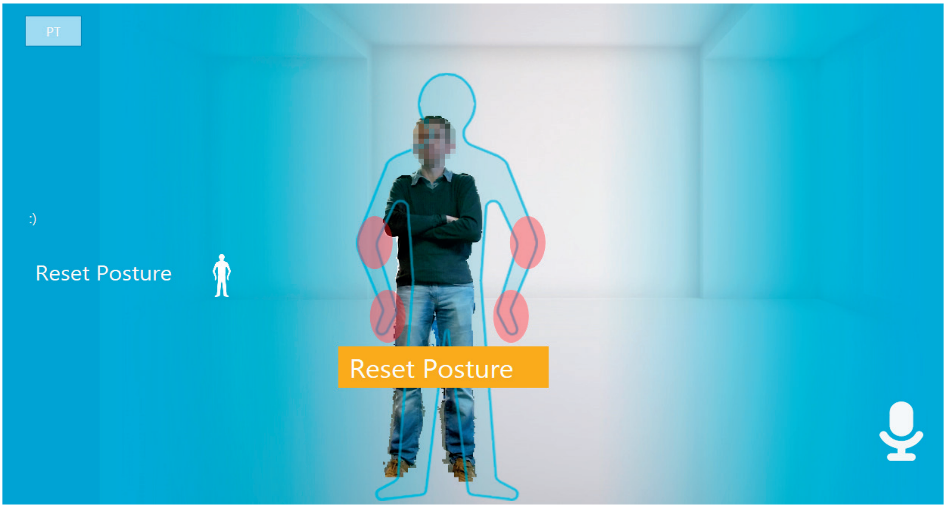

Figure 7.1 PT telling the user to correct the posture.

Self-reflection module

The self-reflection module of the PT has the purpose to help learners to increase their awareness regarding their performance while reflecting on it. It consists of six different sub-modules: *Pauses Report, Posture Report, Gesture Report, Overall Performance Report, Future Improvement, and Improvement Text.*

Pauses Report is designed to help the learner to reflect about her use of pauses during the practice session (see Figure 7.2). The first item presented in this report is a timeline that shows the learner her speaking and silent moments that were captured during the practice session. This timeline also shows the total number of pauses, the average pausing time and the average speaking time. The second item of this report asks the learner two questions:

- “Are you using your pauses with purpose?”
- “How can you improve your use of pauses?”

The second question comes up with a text-field allowing the learner to type an answer.

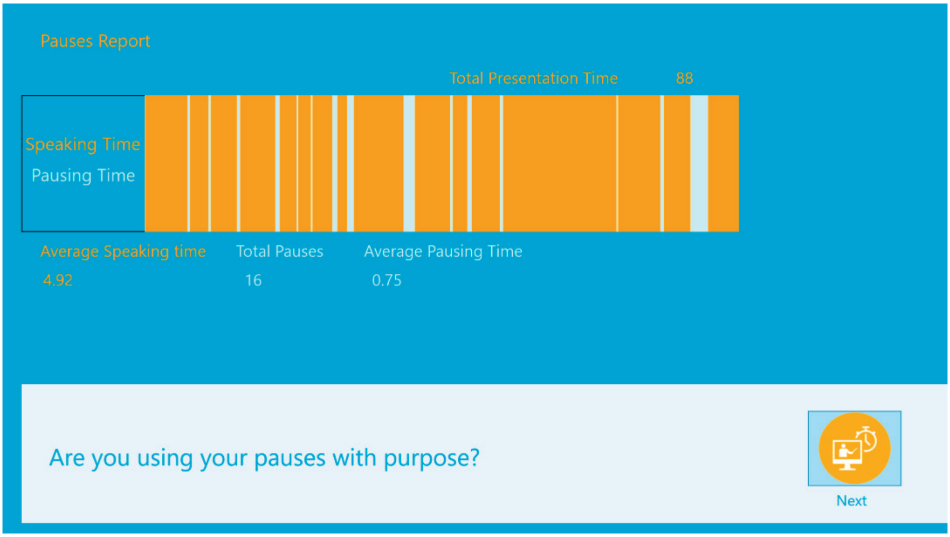

Figure 7.2 Pauses Report sub-module.

Posture Report (Figure 7.3. Left) is designed to help the learner to reflect about her posture during the presentation. The first item displayed in this sub-module is a set of three screenshots captured in the moments that the PT captured a “posture mistake” during the practiced presentation. In case that the PT identified less than three “posture mistakes” during the practice it will show the learner screenshots of random moments from the presentation. The second item in this sub-module asks the learner two questions:

- “The attitude reflected in your posture, is the same attitude that you want to convey?”
- “What would you improve from your posture?”

The second question comes with a text-field allowing the learner to provide an answer.

Gesture Report (Figure 7.3 Right) is designed to help the learner to reflect about her use of gestures. The first item presented in this module shows a timeline that indicates the moments during the practice presentation where gestures were identified. The second item shows three screenshots taken while the learner was using a gesture during her practice. The third item of this sub-module asks the learner two questions:

- “Is there a meaning behind your gestures?”
- “What gestures can you add to support your communication?”

The second question comes with a text-field allowing the learner to type an answer.

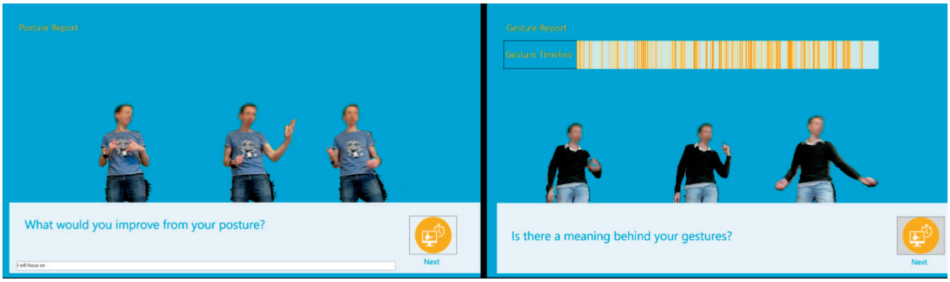

Figure 7.3 Left: Posture Report; Right: Gesture Report

Overall performance Report (Figure 7.4) presents the learner with a timeline showing all the identified events captured by the PT during the practiced presentation. It shows in red the moments where a "mistake" was identified, in green the moments where a positive behavior was identified (e.g. smiling). It also shows with small icons the moments where the feedback of the PT was displayed.

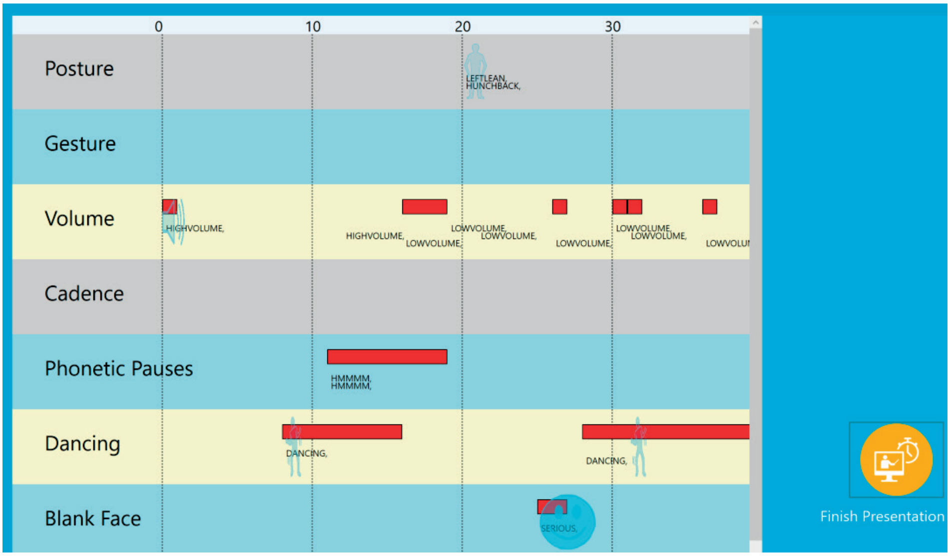

Figure 7.4 Overall performance report showing the events capture by the PT during practice

Future improvement (Figure 7.5 Left) asks the learner "what would you like to improve for your future presentation?". This sub-module allows the user to select one of the aspects that can currently be trained using the PT: Posture, Voice Volume, Gestures, Pauses, and Facial expression. If the learner selects Posture, Gestures or Pauses then during the following training session her *Improvement Text* (Figure 7.5 Right) will be displayed. The text displayed in the *Improvement Text* corresponds to answer given by the learner to the second question of the corresponding report. For example in the case that the learner selects to improve on her Posture, then the *Improvement Text* displayed during her following training session is the answer she gave to the question "What would you improve from your posture?" from the *Self-reflection Posture Report.*

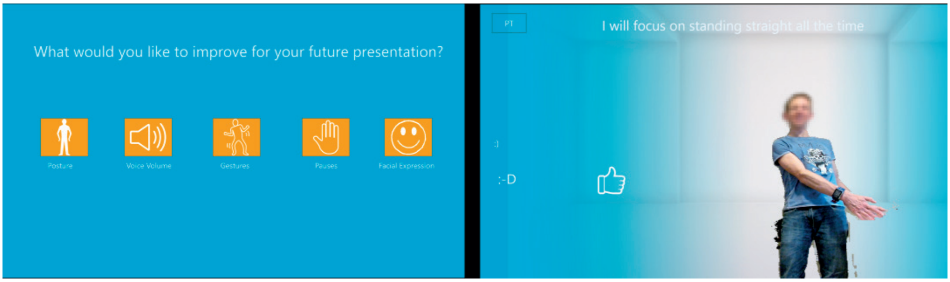

Figure 7.5 Left: Future Improvement Screen. Right: Practice session showing Improvement Text on top

Method

In this study we conducted user-tests (Nielsen, 1994) in order to evaluate the self-reflection module of the PT. The objectives for conducting these tests were the following:

- *Objective* 1: Identify perceived difficulty for learners to correctly interpret the different items from the self-reflection module.
- *Objective* 2: Identify whether the different items help learners to become aware and reflect about their performance.
- *Objective* 3: Identify the influence of the Self-Reflection module on the learners' decision to select what to improve for future practice sessions.
- *Objective* 4: Explore the influence of the Self-reflection module in the learners' performance.

Study Context

We conducted this study in the setting of a course in entrepreneurship for master students in a university. For this course students are divided in teams. During the course each team is required to develop and present an entrepreneurial product or service. Presenting their project effectively is an important aspect of the course; therefore during the course students receive guidance regarding their presentation skills. This study was conducted five weeks after the students had their first public speaking lecture for the course.

Study Procedure

Twelve participants, nine males and three females between the age of 24 and 28 years took part in the study. To prepare for the study, students got the homework to prepare a 60 to 120 seconds long pitch regarding their project. One week later the user-tests were conducted during a two-hour session slot.

For the user-tests participants individually entered into a classroom with the PT. After arriving the experimenter gave the student a brief description of the task and a brief description of the feedback from the PT. Then the student practiced the pitch two times using the PT. After the two practice sessions the student filled in a questionnaire regarding the self-reflection module of the PT.

Apparatus and Material

The version of the PT that includes the self-reflection module was used as the intervention tool for this study. The log files generated by the PT were used to measure the performance of the participants. The log files included all the events captured during the practice sessions e.g. posture, gesture, volume, phonetic pauses, facial expressions and cadence mistakes. These log files also contained the selections made by the participants for future improvements.

A post-test questionnaire was used to inquire participants about their experience with the PT's self-reflection module. This questionnaire was divided in segments that align with the self-reflection sub-modules of the PT: *Pause report*, *Posture report*, *Gesture report*, *Overall performance report* and *Future improvement*. The items in the questionnaire inquired about the difficulty to interpret the different timelines displayed in the reports, and the perceived usefulness of the elements, i.e. helping learners to become aware of their performance and reflect on how to improve in the future.

During the experimental sessions the experimenter took notes regarding the use of the self-reflection module and performance of the participants.

Results

Results from the post-test questionnaire regarding the *Pause report* are displayed in Table 7.1. The results show that generally the *Pause report* helped participants to reflect about the use of pauses. The element that received the highest rating with a mean score of 4.22 out of 5 turned out to be the question: "Are you using your pauses with purpose?". As an extra remark one participant commented the following: "The timeline make me realize that my usual pauses are too short."

Table 7.1 Scores from the post-test questionnaire regarding the *Pause report*

Item from the questionnaire	Mean and standard deviation (1 totally disagree – 5 totally agree)
The timeline for speaking time and pausing time is easy to interpret.	4.11 (0.93)
The timeline helped me to remember what I did during the presentation	3.33 (1.12)
The question: "Are you using your pauses with purpose?" helped me to reflect about my performance.	4.22 (0.67)
The question "How can you improve your use of pauses?" helped me to think on how to improve my future performances	3.67 (1.41)
Overall the *Pause report* helped me to reflect about my use of pauses	3.89 (0.78)

Table 7.2 displays the results from the post-test questionnaire regarding the *Posture report*. Overall the *Posture report* helped participants to reflect about their posture. The item that received the best score with a mean of 4.33 out of 5 was the question: "What would you improve from your posture?".

Table 7.2 Scores from the post-test questionnaire regarding the *Posture report*

Item from the questionnaire	Mean and standard deviation (1 totally disagree – 5 totally agree)
The pictures of me giving the presentation helped me to become aware of how my posture is perceived by the audience.	4.22 (0.97)
The question: "The attitude reflected in your posture, is the same attitude that you want to convey?" helped me to reflect about my performance.	4.11 (0.93)
The question "What would you improve from your posture?" helped me to think on how to improve my future performances	4.33 (0.71)
Overall the *Posture report* helped me to reflect about my posture.	4.11 (0.78)

Table 7.3 displays the results from the post-test questionnaire regarding the *Gesture report*. Overall according to the participants the *Gesture report* helped them to reflect about their use of gestures. The screenshots captured of the participants while doing a gesture was the element of the Gesture report that received the highest score with a mean of 4.67 out of 5. As an extra comment one participant suggested to also record some videos for the captured gestures.

Table 7.3 Scores from the post-test questionnaire regarding the *Gesture report*

Item from the questionnaire	Mean and standard deviation (1 totally disagree – 5 totally agree)
The gesture timeline is easy to interpret	3.22 (1.09)
The gesture timeline helped me to become aware of how many gestures I used during my presentation	3.89 (0.78)
The pictures of me using gestures helped me to become aware of how my gestures are perceived by the audience.	4.67 (0.50)
The question: "Is there a meaning behind your gestures?" helped me to reflect about my performance.	4.33 (0.50)
The question "What gestures can you add to support the communication of your message?" helped me to think on how to improve my future performances	3.67 (1.66)
Overall the *Gesture report* helped me to reflect about my use of gestures	4.11 (0.93)

Results from the post-test questionnaire regarding the *Overall performance report and Future improvements* are displayed in Table 7.4. In summary the *Overall performance report* was perceived as easy to interpret, helpful in terms of reflecting about the overall performance and helpful on reflecting how to improve future performances. One participant commented that it was difficult to connect the problems shown in the timeline with the things done during training. Generally participants liked the idea to be asked by the PT on what skill they want to focus for the following practice sessions. Most of them also considered it a good feature to display on top of the screen what they want to improve during the next practice session. Only one commented that having this extra information is overwhelming.

Table 7.4 Scores from the post-test questionnaire regarding the *Overall performance report* and *Future Improvements*

Item from the questionnaire	Mean and standard deviation (1 totally disagree – 5 totally agree)
The Overall performance report is easy to interpret	4 (0.71)
The Overall performance report helped me to become aware of my performance.	3.89 (1.17)
The Overall performance report helped me to think on how to improve my future performances	3.78 (1.39)
It is a good concept that the PT asks: "What would you like to improve for your future presentation?"	4.33 (1.32)
Seeing my answer on top of the screen of what I want to focus during my presentation is helpful.	3.67 (1.22)
My selection regarding what to improve on a following session was based on (Multiple selections were possible):	Pause report - 6 participants Gesture report – 4 participants Practice Feedback – 2 participants Posture report – 1 participant

We analyzed the performance of the participants for both of the practice sessions using the logged files generated by the PT. In its current version the PT is able to analyze behaviors that are considered mistakes. To evaluate the performance of the participants for each of the practice sessions, we calculated the percentage of time that a mistake was identified during a practice session (pTM). To calculate the pTM we add the duration of all the mistakes captured by the PT during a practice session, and divided this added mistake time by the total duration of the practice session. Table 7.5 displays the mean and standard deviation pTM values for the first and second practice session in this study. Results show that on average participants during the second practice session improved in all aspects. The aspect that received the worst evaluation for the first session was use of pauses, followed by used of gestures and then voice volume. In the second practice session the use of pauses got the worst assessment, followed by voice volume and use of gestures. The aspect displaying the biggest improvement for both sessions was the use of gestures, followed by the use of pauses.

Table 7.5 pTM scores captured during the practice sessions (mean and standard deviation).

	Posture pTM	Volume pTM	Pauses pTM	Blank F. pTM	Gestures pTM	Dancing pTM	P. Pauses pTM	Total pTM
1st Session	0.017 (0.05)	0.153 (0.10)	0.290 (0.19)	0.009 (0.21)	0.238 (0.28)	0.000 (0.00)	0.032 (0.02)	**0.739** **(0.47)**
2nd Session	0.009 (0.04)	0.133 (0.11)	0.197 (0.22)	0.001 (0.22)	0.082 (0.17)	0.012 (0.02)	0.016 (0.02)	**0.451** **(0.33)**
Mean Difference	0.008	0.020	0.093	0.008	0.156	0.012	0.016	**0.313**

We examined the possible effects that the selection to improve a specific behavior had on the performance on this behavior in the following practice session. To do that, we measured the improvement between practice sessions. We grouped the participants who made the same selections. Then we measured the improvement that they had for the selected behavior. We obtained this improvement by measuring the difference of the pTM scores between the first and second practice session for the selected behavior. Finally we compared the mean improvement from the group that selected the specific behavior against the mean improvement from the whole set of participants. Table 7.6 shows the comparison of the improvements from the groups that selected a specific behavior against the whole set of participants. The results on the table show that participants who selected to focus on the use Pauses, Gestures or Facial expressions between the 1st and 2nd practice session displayed on average a bigger improvement for their selected behavior, than the average improvements for these behaviors taking into account all participants. The exception is Posture, where the performance of the participant who selected to focus on Posture, become worse in terms of Posture during the second practice session.

Table 7.6 Comparison of the captured improvements grouped by the participants who selected to improve a specific behavior against the whole set of participants.

	Improvement 1st and 2nd practice session for participants who selected to improve the specific behavior	Improvement between 1st and 2nd practice session for all participants
Pauses	0.226	0.093
Posture	-0.021	0.008
Gestures	0.255	0.156
Facial Expressions	0.05	0.008

The experimenter observed that in the first few moments of the second practice session participants did put a lot of effort in improving what they selected to improve. For example usually participants make the first pause once the PT sends the feedback that is time to make a pause, currently this time is set up to 15 seconds of speaking without pausing. From the logs of the presentation trainer is possible to observe that the six participants who selected to improve their use of pauses, made a deliberate pause before the first 15 seconds of the second practice session. After that, their following pauses where made after the PT indicated them to do so. Similar behavior was observed with the participants who selected to improve their gestures. During the first moments of their second practice session they introduced some iconic gestures, later they stopped with the iconic gestures and returned to the usual way of moving their hands while speaking. The same was observed with the participant who wanted to display a "more open posture". The participant started the pitch with arms open, palms of hands facing to the front and after few seconds, the participant returned to the ordinary posture.

One final observation happened while the participants were interacting with the self-reflection module. During this interaction four participants commented out-loud that in order to improve their performance, it would be necessary to modify their pitch and rewrite it based on the information presented by self-reflection module.

Discussion

Results from the post-test questionnaire allowed us identify that the different elements of the self-reflection module of the PT were interpreted correctly by participants without major difficulties. Results also indicate that the different elements of the self-reflection module were perceived as helpful in supporting learners to reflect about their performance. These two outcomes satisfactorily address *Objective* 1 and *Objective* 2 of this study. The post-test questionnaire also positively addresses *Objective* 3 of this study. It shows that the self-reflection module substantially influenced the participants' selections on what to focus on future practice sessions.

Objective 4 of this study deals with exploring the influence of the self-reflection module on the learners' performance. To examine this influence we analyzed the logged data of the PT. The analysis of the logged data shows that the participants that selected a specific behavior to improve, had a slightly bigger improvement in this behavior than the participants who did not select it. However, the number of participants and the difference in improvement are both to small. Therefore, we cannot attribute with certainty that the observed improvements are the result of the interaction with the self-reflection module. Similar results were obtained when looking at the general measured improvements (improvements considering all skills, not only the selected ones to be improved). The general improvements captured in this study are also slightly bigger than the improvements observed in a previous study that used a version of the PT without the self-reflection module (0.313 measured in this study in contrast to 0.284 measured in (Schneider et al., 2016b). Nonetheless, the difference in settings between both studies and the minimal difference in improvements does not allow us to assert that the self-reflection module of the PT influenced the participants' performance. Having said that, observations from this study lead us to consider that the slightly bigger improvements can be attributed to the first few moments of the second practice sessions. During these first few moments it was observed that participants deliberately changed their usual communication practices, and that these deliberate changes quickly fade away. This points out a limitation for this study. The set-up of the study did not provide with the necessary methods to systematically measure the possible subtle differences in performance influenced by the self-reflection module. An important limitation is the constrained amount of practice offered. Just one additional practice session is likely too limited.

One of the most interesting findings in this study is that without being asked, four participants out-loud commented the importance of rewriting their pitch based on the information presented by the self-reflection module. Due to time constrains and study design participants were not allowed to do so. However, these comments are clear indications that the module fulfilled its main purpose. It made participants truly reflect on how to improve their performance. These comments made us reconsider our approach on how to study the influence that self-reflection has in the learners' performance. In this and previous studies with the PT, the learners' performance was measured through the learners' displayed behavior, cognitive changes were not assessed. Therefore the main influence of the self-reflection module might not merely be displayed as machine-measured improvements in behavior. Rather, the main influence of this module relies on the awareness raised on participants to reconsider and adapt their behavior, for further practice sessions with the PT or even better, in real presentations.

Conclusion and Future Work

In recent years the use of multimodal public speaking instructors has been researched, in order to support learners with the practice and feedback needed to develop their public speaking skills. So far studies regarding these instructors have presented promising results showing that learners are able to adapt their behavior based on the feedback provided by these systems. Research has also shown that these changes in behavior also translate to better presentations according to human audiences. Following public speaking experts' suggestions on how to improve these technologies, we added a self-reflection module to the PT and conducted a formative evaluation on it. The module added fits well within theories of reflection (Schön, 1983). With the added module the PT enables now both reflection-in-action (reflection on behavior as it happens, so as to optimize the immediately following action) and reflection-about-action (reflection after the event, to review, analyze, and evaluate the situation, so as to gain insight for improved practice in future) (Van Rosmalen, Börner, Schneider, Petukhova, & Van Helvert, 2015). This evaluation allowed us to draw the following conclusions:

- Learners perceived that the different reports of the self-reflection module helped them to reflect about their performance. These reports confront learners with evidence of events that happened during the practice session (e.g. screen shots, timeline of events), together with questions inquiring whether the presented evidence is aligned with their expectations, and questions asking for means to improve their performance.
- The self-reflection module influences the learners' decision on what they would like to improve on in future practice sessions.
- The self-reflection module does not present a substantial influence in the participants' measured behavior. Likely, only one additional practice is not sufficient.
- The self-reflection module made some participants aware that a new pitch should be rewritten taking in consideration the presented information in order to substantially improve their performance.

To improve the self-reflection module we find it important to continue studying its effect on the learners' performance. This includes systematically exploring the changes in behavior that seem to happen during the first moments of the practice sessions. Closely identifying the changes and timely measuring when they fade. Also provide learners the opportunity to rewrite their pitch or presentation based on their self-reflection, and meticulously study the differences between the old and the newly re-written pitches. Moreover, equally, important, to investigate the optimal amount of practice sessions. Finally investigate whether the self-reflection module is able to influence the learners' performance, in a way that a human audience is able to recognize.

To finalize, this study instead of providing conclusive evidence on the effects of a self-reflection module for multimodal public speaking coaches, it revealed new paths for future research. Paths that go beyond the exploration of multimodal applications designed to support learners with the automation of their behavior. It revealed paths for investigating how sensor-based public speaking coaches can also support learners with the examination of their performance and making it worth for them.

Chapter VIII

Do you want to be a Superhero? Boosting emotional states with the Booth

Public speaking is usually performed under emotionally charged situations that tend to provoke anxiety in speakers. Anxiety is responsible for undermining executive functions such as reasoning, task flexibility, attention control and performance. Therefore, it is important to support learners in the preparation of a supportive mindset. *The Booth* is an application designed to get learners into a powerful and resourceful emotional state. It was developed with the intention to study how sensor-based applications can be used to support learners with the preparation of a supportive mindset. The study in this chapter presents a two-step user study. Results of the first step show that the use of *the Booth* induced a positive emotional state on users. Results from the second step suggest that using *the Booth* helps learners to emotionally prepare for speaking to the public.

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Introduction

Educational researchers, teachers, employers, and policy makers have highlighted the relevance of using educational systems to provide learners with a set of 21st century skills, such as communication and social skills that will help them to function effectively at work and in their leisure time (Ananiadou, & Claro, 2009; Dede, 2007; Kalantzis, & Cope, 2012). One variable that has a direct impact in performing well is the emotional state of the performer. Research has shown that the emotional state of the performer has an influence on sports (Cohn, 1991; Rumbold, Fletcher, & Daniels, 2012), creativity (Lin, Tsai, Lin, & Chen, 2014), workplace (Beal, Weiss, Barros, & MacDermid, 2005) and academic performance (Cassady, & Johnson, 2002). Performance of learners declines when learners are faced with a feeling of powerlessness. The feeling is usually triggered by stressful events that require learners to fully use their cognitive capacities. This activates the behavioral inhibition system in learners; it forces them to focus on threats rather than on opportunities (Cuddy, 2016b). Powerlessness also undermines executive functions such as reasoning, task flexibility, attention control, and performance (Derakshan, & Eysenck, 2009). Moreover, it keeps learners from post processing the event days later (Gaydukevych, & Kocovski, 2012). To avoid feeling powerlessness and to improve performance, research has shown that at some point the learner should stop preparing content and start preparing a supportive mindset (Raman, R., Chadee, Roxas, & Michailova, 2013; Cuddy, 2016a). We consider this mindset preparation to be particularly important for the preparation of events that are usually performed in emotionally charged and stressful situations, such as oral presentations, negotiations, debates, interviews, etc.

The emotional state of learners is usually overlooked in common educational practices (Alsop, & Watts, 2013; Pierre, & Oughton, 2007) and especially technology enhanced learning applications (Schneider et al., 2015a) thus failing to provide learners with some of the tools required to perform well. Therefore, to assist learners with their affective preparation, we developed *the Booth* an application designed to bring learners into an emotional state that allows them to perform well. In this article we present a study conducted in two steps. First we evaluated *the Booth* and the impact of its use in normal working day conditions, where participants did not have to prepare for any special event. In the second step we explored the effects of *the Booth* when used as a preparation tool before giving a public presentation on a scientific conference.

Background

The integration of sensor technologies with computers systems has led to the creation of immersive learning applications designed to support the acquisition of a wide variety of skills (Schneider et al., 2015a). Examples of these skills include artistic (Van Der Linden et al., 2013; Bevilacqua et al., 2007), sports (Baca & Kornfeind, 2006; Spelmezan et al., 2009), and social and communication skills (Schneider et al., 2016b; Damian et al., 2015) among others. Most of these sensor-based applications support learners with the practice of their skills while receiving feedback regarding their performance. This support helps learners to develop the techniques required for the skills. For example the prototype described in (Schneider et al., 2016b) allows learners to practice their presentations while giving them feedback regarding their posture, use of gestures, pauses, voice, etc.

Fewer sensor-based applications support learners affectively by allowing them to practice in simulated, less stressful environments. Examples of this can be seen in applications designed to train interview skills, where the learner is allowed to practice while talking to an avatar (Hoque et al., 2013) and also in applications to train presentation skills where the learner can practice in front of a virtual audience (Barmaki, & Hughes, 2015; Wörtwein et al., 2015).

Creating opportunities for learners to practice on simulated less stressful environments is not the only method that affectively can help them to prepare for emotionally charged situations. In 1890 William James published his theory regarding human psychology, explaining that our feelings are not the ones guiding our actions, on the contrary our actions are the ones guiding our feelings (James, 1890). Since then research in line with this theory has given rise to a series of effective exercises that can help people to decrease negative emotions such as anxiety and stress, and increase positive emotions such as confidence, happiness (Wiseman, 2012). To the best of our knowledge *the Booth* is currently the only application that guides learners through a series of exercises designed to help them to acquire a powerful emotional state. Hence, helping them with the preparation of a supportive mindset for any type of emotionally charged and stressful events that require the display of 21st century skills.

The Booth

Some superheroes portrayed in popular culture during the second half of the 20th century used to live their life disguised as civilians and turn into superheroes when needed. In some cases, they used a phone booth to quickly change themselves and bring out their superhero persona. *The Booth* is an application that follows this superhero metaphor. Its aim is to guide users through a series of psychological techniques that have shown to help people with the acquisition of a resourceful emotional state, that allows them to have full access to executive functions such as reasoning, task flexibility, attention control, etc. It presents users with a narrative consisting of a series of lectures. Each lecture contains three phases: explanation, exercise, and report (see Figure 8.1), and makes use of different psychological techniques designed to boost the emotional state of the user. From the vast amount of psychological exercises and techniques designed to boost the emotional state, we selected the ones that we found easier to fit with the superhero narrative. In its current version the whole narrative of *the Booth* consists on five lectures and it takes the user between three to eight minutes to go through all of them.

The Booth uses the Microsoft Kinect V2[15] sensor as an input device allowing users to interact through voice commands, gestures, postures and facial expressions.

Figure 8.6 From left to right: Explanation, Exercise and Report from lesson 1.

The Booth Narrative

The narrative of *the Booth* starts when the user stands in front of the Kinect sensor, at that moment the application plays a recorded sound asking the user to raise one hand in case she wants to become a superhero. After raising the hand, the user is requested to select a male or a female character. Then the first lecture starts. The following subsections of this article describe the current lectures incorporated in *the Booth,* including the psychological practices and techniques behind the design of each one of them.

Lecture 1: Superhero Posture

This lecture consists of teaching the learner to stand in the *superhero posture* (see Figure 8.2). To stand in this posture the learner has to stand straight, with both feet firmly on the ground at shoulders width, hands rest at hip level, and smiling. The author in (Cuddy, 2016c) explains, that our own body language communicates back to us and influences our state, claiming that expansive body language increases assertiveness, optimism and resilience while reducing stress. It improves our skills, decision taking, perception and strengths (Arnette, & Ii, 2012). In (Cuddy, Wilmuth, Yap, & Carney, 2015) participants who stood in expansive body postures that express power as preparation for a job interview, significantly outperformed participants who did not use the power postures as preparation. These studies have received some recent criticism because the significant results obtained in them could not be replicated in other studies (Simmons, & Simonsohn, 2017); however, the effects of power posing were not disproved, and standing in the *superhero posture* fits with the narrative of *the Booth*. Facial expressions have also shown to have an effect on people's mental states: e.g. forced smiles have shown to inhibit fear and anxiety in people (Duncan, & Laird, 1980), and make them feel happier (Laird, 1974).

[15] https://developer.microsoft.com/en-us/windows/kinect

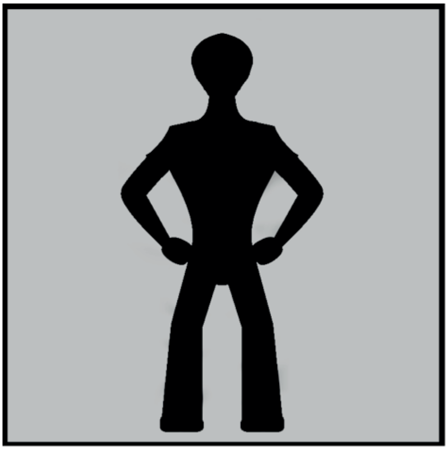

Figure 8.7 Superhero Posture

Once the Kinect sensor recognizes that the learner adopted the superhero posture and smiled, a report of the lecture is displayed on the screen. This report acknowledges the posture of the learner and asks the learner whether she is starting to feel more powerful. During the remainder of the narrative, in case the learner stops smiling or adopts a less expansive, straight and open posture, the Booth will ask her to return to the superhero posture and smile in order to proceed.

Lecture 2:Superhero Powers

In this lecture learners are asked to select three different *superpowers* that fit their personality. In contrast with the superpowers of fictional superheroes that have extraordinary abilities impossible to be replicated by humans, the *superpowers* that can be selected during this lecture are personality traits that to a certain degree all humans have. The available *superpowers* to be selected are: assertiveness, charisma, concentration, confidence, creativity, empathy, intelligence, memory, presence and willpower. The purpose of selecting this type of *superpowers* is to help learners to be in touch with the best version of themselves (Roberts, Dutton, Spreitzer, Heaphy, & Quinn, 2005), and to emulate self-affirmation techniques (Cohen, & Sherman, 2014). These techniques have shown to help people in reducing their anxiety for stressful situations, helping people to become more open to feedback and improve their problem solving skills under stress (Creswell, Welch, Taylor, Sherman, Gruenewald, & Mann, 2005). Once the learner selects three super powers, the report of the lecture appears and rhetorically asks the learner to imagine how would she stand, walk and talk when having these *superpowers*.

Lecture 3: Inspiration

Exposing or priming people with certain kinds of concepts has shown to have an effect on people's behavior, e.g. in (Kawakami, Dovidio, & Dijksterhuis, 2003), participants primed with concepts related to the elderly adopted more conservative attitudes and behaviors in contrast to participants who were not primed. This priming effect can also lead to a positive behavioral change as shown in (Schmid Mast, Jonas, & Hall, 2009), where participants exposed to words that express personal power enhanced their ability to read and relate to people. Following this principle, in this lecture the learner has to select one value that she finds inspiring out of a list of 18 words including values such as courage, kindness, charisma, honesty, loyalty, presence, etc. After the value is selected the report of the lecture appears and rhetorically asks the learner to reflect on how to welcome more of the selected value into her daily life.

Lecture 4: Saving the World

During this lecture, learners have to select three concepts that they as superheroes would like to bring to the world. The concepts available for selection are: acceptance, clarity, joy, justice, kindness, love, passion, peace, respect and understanding. After making the selection, the report of the lecture appears. The report asks the learner to reflect on how she could use the previously selected *superpowers* in order to bring more of the recently selected concepts to the world (see Figure 8.3). A screenshot of this report is automatically posted on Twitter for learners to look at it and share it after the intervention. This lecture brings back the concept of self-affirmation, exposing learners to encouraging ideas, and aims to shift the mind of the learner into helping others. Helping others while being in a positive state has shown to increase happiness (Otake, Shimai, Tanaka-Matsumi, Otsui, & Fredrickson, 2006), and life satisfaction (Buchanan, & Bardi, 1992).

Figure 8.8 Screenshot of the report of Lecture 4

Lecture 5: Celebration

In this lecture the learner is asked to raise both arms, remember a time when they won something and how they felt at that moment. While the learner raises their arms, *the Booth* starts playing a popular tune of music (Vangelis, 1981) that has been used to illustrate sports achievements since 1981. Raising both of our arms above our shoulders forming a V-shape is a universal expression of power. Humans from all cultures use that posture to express victory and celebration (Tracy, & Matsumoto, 2008). After finishing the lecture *the Booth* displays the following quote: "Don't fake it 'till you make it. Fake it 'till you become it" (Cuddy, 2012).

Evaluation

The evaluation of *the Booth* presented in this article consists of a study conducted in two steps. In the first step of the study we evaluated the use of *the Booth* and its impact on participants as a standalone task. In the second step of the study we explored the use of *the Booth* and its impact as a preparation tool for oral presentations during a conference.

First Step

Before testing whether *the Booth* is suitable to be used as an emotional preparation tool for an emotionally charged event, we first needed to find an answer to the following research questions:

- RQ1a) Are there any usability issues that obstruct the use of *the Booth*?
- RQ1b) Does *the Booth* have a positive effect on the emotional state of users?

The objective of the first research question is to identify the usability issues that can hinder the experience of using *the Booth*. The objective of the second research question is to investigate the influence that the use of *the Booth* has on the emotional state of users in a neutral scenario, in order to determine whether it would be appropriate to use it during stressful situation.

To study these two research questions, participants used *the Booth* as a standalone task during a regular working day, where they did not have to prepare for any special event.

Participants
A total of 40 participants, 22 females and 18 males took part in this first evaluation of *the Booth*. The age of the participants ranged from 21 to 64, with an average age of 41 years. All participants were professionals working at a university with similar European cultural background. We recruited the participants by personally asking them to participate in our study.

Apparatus and Materials

The apparatuses used for this study were a 50-inch monitor, a Microsoft Kinect V2 sensor and a laptop running *the Booth*. To evaluate the effects of the Booth we used a pre-questionnaire and a post-questionnaire. The pre-questionnaire inquired the current emotional state of the participants. This questionnaire consisted of one item asking participants to select one or multiple choices from a list of 23 different emotions, including the option to name other emotions. The purpose was to have a balanced list of emotional states therefore the list included 11 and 11 negative emotions. The remaining listed emotion was Neutral. Table 8.1 displays the list of emotions grouped by positive and negative emotions.

The post-questionnaire consisted on seven items. The first item inquired the current emotional state of the participant, same as the item from the pre-questionnaire. This post-questionnaire had also four items using Likert-scaled items inquiring about the confidence of the participant, enjoyment of using the *Booth*, easiness of use, and sharing the experience in social networks. It had one more final item asking participants to share some remarks. Finally during the interaction an observer was taking notes.

Table 8.1 List of Emotions grouped by positive and negative

Positive		Negative	
Confident	Happy	Angry	Pessimistic
Energetic	Joyful	Annoyed	Selfish
Enthusiastic	Motivated	Anxious	Stressed
Excited	Optimistic	Bored	Tired
Generous	Powerful	Depressed	Upset
Grateful		Discouraged	

Method

Participants arrived to the session and were asked to fill in the pre-questionnaire. Then they were asked to stand at a distance of approximately 2.5m in front of the monitor and the sensor. At this point the experimenter explained the participant how to interact with the system (using gestures and/or voice commands). After the explanation, the experimenter started *the Booth*. Participants interacted with *the Booth* following its whole narrative. Finally they filled in the post-questionnaire. The whole procedure lasted around 10 minutes in total.

Results

Regarding usability, the tests show no substantial usability issues that could obstruct the interaction with *the Booth*. We observed that participants preferred to use voice commands instead of gestures. One minor issue observed has to do with the recognition of the voice commands, some commands had to be repeated several times. The most problematic command was *Start*. This command was used in order to start each lecture. In order to solve this issue for the second step of the study we substituted the command *Start* with *Next*, which showed to be recognized better by the system.

Results regarding the user experience of *the Booth* extracted from the first study are displayed in Table 8.2. The scores given by the participants range from one to five, with five showing a total agreement with the statement. These results show that on average participants reported their experience of using *the Booth* as enjoyable. On average they found *the Booth* relatively easy to use, and reported to feel a bit more confident after using it.

Table 8.2 User Experience Results

Question	Mean	Standard Deviation
• I enjoy using the Booth	4.15	0.7
• I Felt more Confident after using the Booth	3.4	0.9
• The Booth is easy to use	3.65	1
• I like to share my experience with the Booth	3.35	1

When analyzing the self-reported emotional state of the participants before and after using *the Booth* substantial differences can be observed. 36 out of the 40 participants reported a change in their emotional state.

Before using the Booth, *Neutral* got the most selections by participants followed by *Happy* and *Motivated*. After using *the Booth, Happy* was the emotion that got the most selections followed by *Energetic* and *Enthusiastic*. Table 8.3 displays all the self-reported emotional states before and after using *the Booth*.

To continue with our analysis on the effects on the emotional state of participants influenced by the use of *the Booth* we separated the different emotions into two groups: negative emotions and positive emotions (see table 1). We conducted a t-test to compare the means of the negative emotions reported by the participants before and after using *the Booth*. Participants before the treatment reported more negative emotions (M=0.53, SD=0.7) than after the treatment (M=0.15, SD=0.36); $t(58)=2.96$, $p=0.004$. These results show that using *the Booth* helped participants to reduce their negative emotions.

We also conducted a *t*-test to compare the amount of positive emotions reported by the participants before and after using *the Booth*. Participants before the treatment reported a significant lower amount of positive emotions (M=1.62, SD=1.41) in comparison of the reported positive emotions after the treatment (M=3.38, SD=1.69); $t(74)=4.85$, $p<.001$. These results indicate that the use of *the Booth* helped to induce positive emotions on the participants.

Figure 8.4 shows the differences between the reported negative and positive emotions grouped by the number of participants before and after using *the Booth* grouped by the number of participants.

Table 8.3 Self-Reported Emotional State (alphabetically sorted in negative, neutral and positive emotions)

Emotion	Before using the Booth	After using the Booth	Difference
Angry	0	0	0
Annoyed	0	0	0
Ashamed	0	1	1
Anxious	3	0	-3
Bored	1	0	-1
Depressed	1	0	-1
Discouraged	0	0	0
Pessimistic	0	0	0
Selfish	0	0	0
Stressed	7	2	-5
Tired	10	3	-7
Upset	0	0	0
Neutral	26	5	-21
Confident	12	17	5
Energetic	4	19	15
Enthusiastic	6	18	12
Excited	1	10	9
Generous	4	1	-3
Grateful	3	2	-1
Happy	13	26	13
Joyful	7	17	10
Motivated	13	15	2
Optimistic	0	0	0
Powerful	3	11	8
Relaxed	1	1	0
Thoughtful	1	0	-1

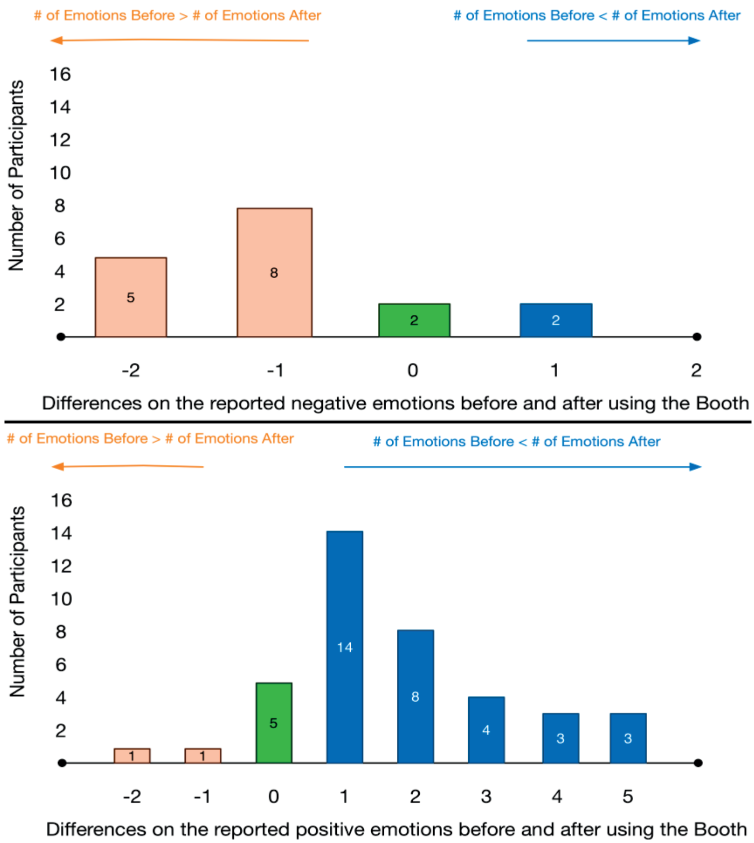

Figure 8.9 Top: the differences for the reported negative emotions grouped by the number of participants before and after using the Booth. Bottom: the differences for the reported positive emotions grouped by number of participants before and after using the Booth.

Second Step

After observing that there were no important usability issues able to hinder the use of *the Booth*, and determining that it has a positive effect in the emotional state of users, we moved to the second step of the study. The purpose of this second step of the study was to explore *the Booth* as a tool designed to help learners with the preparation of a supportive mindset for emotionally charged and stressful events that require them to display their skills. Therefore for this second step, we selected to test *the Booth* in the context of a scientific conference in technology-enhanced learning, where participants are required to orally present their research. This second step of the study was guided by the following research question:

RQ2) Does the use of *the Booth* help people to acquire a resourceful and powerful emotional state that allows them to perform well during a presentation?

Participants

A total of 18 participants, seven females and 11 males took part on this second step of the study. The age of the participants ranged from 23 to 62 with an average age of 36. For this second study we had a control and a treatment group with nine participants on each group. The assignation of the participants into the different groups was done according to the schedule of the conference presentations. Speakers scheduled as first speakers of their corresponding sessions were assigned to the treatment group, since they could use *the Booth* in between the breaks of the conference just before their presentation. Speakers who had to give their presentation in between sessions were assigned to the control group.

Apparatus and Materials

For the treatment group in this study we used a laptop computer to run *the Booth*, and a Microsoft Kinect V2 sensor. *The Booth* was displayed either through a projection, on a 50-inches monitor or on the laptop screen depending on the equipment that was available for the conduction of each individual test. Participants from the treatment group got the task of studying their slides before giving their presentation. Both groups of participants filled in three questionnaires: a pre-questionnaire, a post-questionnaire, and a post-presentation questionnaire. The item used to determine the emotional state of the participant was the same one that was used on the first step of the study. The pre and post-questionnaires consisted of this one item. The post-presentation questionnaire consisted of two items: a Likert-Scaled item inquiring the self-satisfaction of the given presentation, and a second item where participants could express additional comments.

Method

The tests started with asking participants to fill in the pre-questionnaire some 15 minutes before the start of their presentations. On the second step participants of the treatment group were asked to interact with *the Booth.* For this interaction participants stood some 2.5m in front of the monitor and sensor, and were quickly debriefed on how to interact with it. The experimenter started *the Booth,* and participants used it through its whole narrative. After interacting with *the Booth* participants filled in the post-questionnaire. Instead of using *the Booth* participants from the control group were asked to study their slides as they normally do before giving a presentation. After that, participants from the control group answered the post-questionnaire. At the end of their respective presentations, participants from both groups were asked to answer the post-presentation questionnaire.

Results

Table 8.4 shows the self-reported emotional state of the participants from the control group and treatment group before and after studying the slides in the case of the control group, and before and after using *the Booth* for the treatment group.

Table 8.4 Self-Reported Emotional State for Control and Treatment Group

	Control Group			Treatment Group		
Emotion	Before	After	Diff	Before	After	Diff
Angry	0	0	0	0	0	0
Annoyed	0	0	0	1	0	-1
Ashamed	0	0	0	0	0	0
Anxious	5	4	-1	4	1	-3
Bored	0	0	0	1	0	-1
Depressed	1	0	-1	0	0	0
Discouraged	0	0	0	0	0	0
Nervous	0	0	0	2	0	-2
Pessimistic	1	1	0	1	0	-1
Shaky	1	1	0	0	0	0
Selfish	0	0	0	0	0	0
Stressed	4	4	0	3	2	-1
Tired	0	2	2	5	3	-2
Upset	0	0	0	0	0	0
Neutral	0	0	0	2	1	-1
Confident	5	5	0	0	3	3
Energetic	2	2	0	2	4	2
Enthusiastic	2	2	0	3	6	3
Excited	3	3	0	4	2	-2
Focused	0	1	1	0	0	0
Generous	1	1	0	0	0	0
Grateful	1	1	0	1	0	-1
Happy	3	0	-3	2	5	3
Joyful	1	1	0	0	6	6
Motivated	4	4	0	5	5	0
Optimistic	3	4	1	4	5	1
Powerful	0	0	0	0	3	3
Relaxed	0	0	0	0	1	1

Regarding the self-reported emotional states before and after studying the slides, six emotions presented a difference between the pre and post-questionnaire. The biggest difference obtained deals with the self-reported happiness of the participants. Three participants reported to be happy before the preparation and did not report to be happy after it.

In the case of the treatment group 18 emotions presented a difference between the self-reported emotional states before and after the use of *the Booth*. The biggest difference deals with the self-reported joy from the participants, showing that six participants reported to feel joyful after the intervention. The self-report of participants shows that emotions such feeling anxious, nervous or stressed, which usually have a negative effect on presenters, decreased after *the Booth* intervention. On the contrast, the reports on opposite emotions such as feeling confident, powerful and optimistic increased after the intervention. In general after using *the Booth* participants reported an increment of emotional states associated to a positive connotation and a decrement of emotional states associated to a negative one.

Similar as in the previous step of the study we grouped the emotions into negative and positive ones. We compared the amount of self-reported negative emotions for both groups before the intervention using a heteroscedastic t-test. Before the intervention the control group reported slightly less negative emotions (M=1.33, SD=1.41) than the treatment group (M=1.89, SD, 1.23); t(16)=0.88, p=0.34. This shows no significant difference between the selections of negative emotions for both groups.

We compared once more the amount of self-reported negative emotions after the interventions using a heteroscedastic t-test. In this case the control group reported to have more negative emotions (M=1.44, SD=1.13) than the treatment group (M=0.67, SD=0.87): t(15)=1.64, p=0.12. Results from this test show a non-significant trend in the direction that after using *the Booth* participants will report to have less negative emotions than participants who studied their slides.

We conducted paired t-tests comparing the means between the reported negative emotions before and after the intervention for both groups. The purpose of these tests is to explore the influence of each intervention in the amount of self-reported negative emotions. In the case of the control group before studying the slides participants reported to have slightly less negative emotions (M=1.33, SD=1.41) than after studying them (M=1.44, SD=1.13); $t(8)=0.26$, $p=0.80$. The difference observed is too small to tell if studying slides had an influence on the reported negative emotions.

In the case of the treatment group, results from the paired t-test show that the amount of negative emotions reported before using *the Booth* was significantly higher (M=1.89, SD=1.23) than after the treatment (M=0.67, SD=0.87); $t(8)=3.35$, $p=.01$. These results show that the use of *the Booth* had an influence in reducing the amount of self-reported negative emotions.

Figure 8.5 shows a comparison of the differences between the reported negative emotions grouped by the number of participants from both groups before and after the received treatment. The figure reveals that two participants reduced the amount of negative emotions after studying the slides, while six participants reduced the amount of negative emotions after using *the Booth*. Figure 8.5 also shows that two participants from the control group reported an increment in the amount of negative emotions, while none of the participants from the treatment group reported an increment.

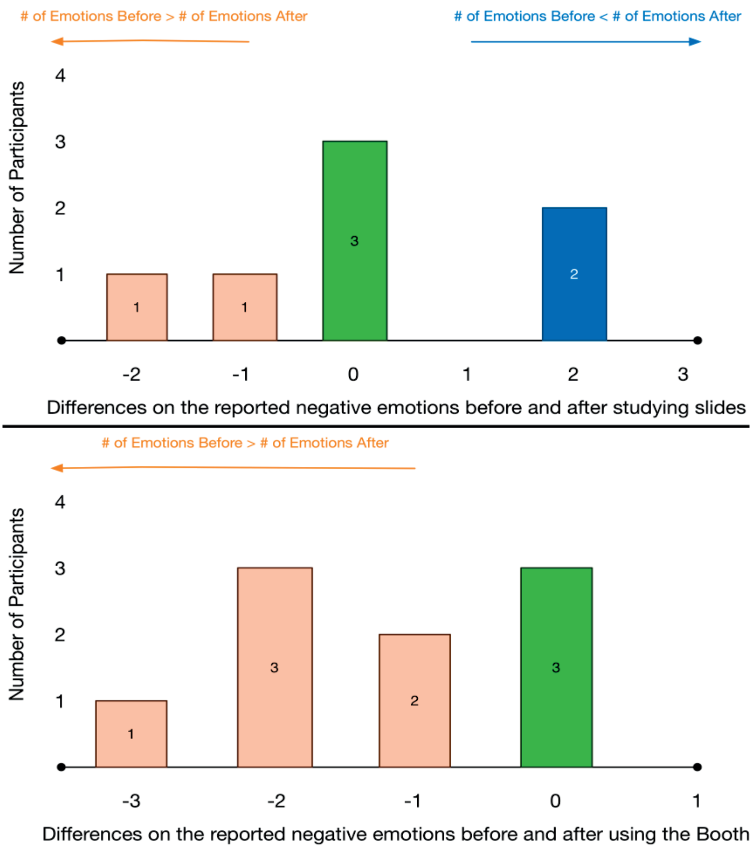

Figure 8.10 Top: the differences for the reported number of negative emotions grouped by the number of participants from the control group. Bottom: the differences for the reported number of negative emotions grouped by the number of participants from the treatment group.

We conducted a heteroscedastic t-test to compare the self-reported positive emotions for both groups before the interventions. Results from this test show that the control group reported to have slightly more positive emotions (M=2.78, SD=3,03) than the treatment group (M=2.33, SD=1.58); t(12)=0.39, p=0.7. Results from this test reveal no significant difference in the selection of positive emotions between both groups.

We conducted the heteroscedastic t-test once more to compare the self-reported positive emotions after the interventions. Results from this test show that the control group reported to have *marginally* significant less positive emotions (M=2.44, SD=2) than the treatment group (M=4.44, SD=2.18); t(16)=2.02, p=0,06.

To explore the influence of each intervention in the amount of self-reported positive emotions, we used a paired *t*-test to compare the means of self-reported positive emotions before and after the treatment for both groups. In the case of the control group participants reported to have slightly more positive emotions before studying the slides (M=2.78, SD=3.03) than after studying them (M=2.44, SD=2); *t*(8)=0.5, *p*=.63. The difference observed is too small to tell whether studying the slides had an effect in the reported positive emotions of the participants. For the treatment group the amount of reported positive emotions was considerably lower before using *the Booth* (M=2.33, SD= 1.58) than after its use (M=4.44, SD=2.19); $t(8)=3.64$, $p=.004$. These results indicate that the use of *the Booth* helped participants to enter into a positive emotional state.

Figure 8.6 shows a comparison of the differences between the reported positive emotions grouped by the number of participants from both groups before and after the received treatment. This figure shows that three participants from the control group decreased the amount of reported positive emotions after studying the slides, while none of the participants who used *the Booth* reported a decrease in positive emotions. Four participants from the control group reported an increment in their positive emotions in comparison with seven of the participants from the control group.

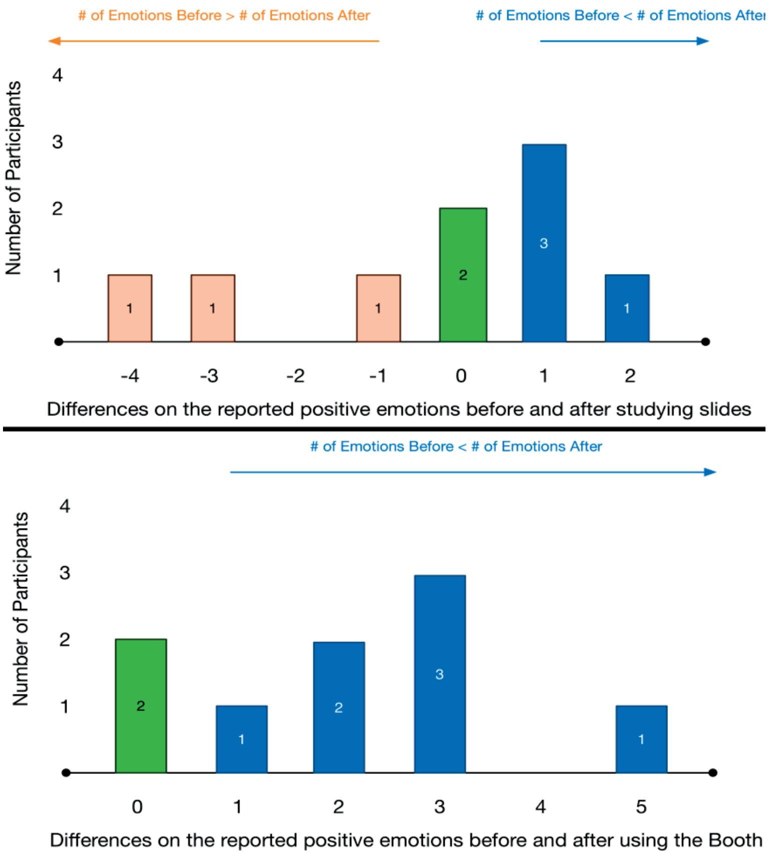

Figure 8.11 Top: the differences for the reported number of positive emotions grouped by the number of participants from the control group. Bottom: the differences for the reported number of positive emotions grouped by the number of participants from the treatment group.

The post-presentation questionnaire asked participants to rate their self-satisfaction of the given presentation; we compared the means of the level of self-satisfaction for both groups using a heteroscedastic t-test. Results from this test show no significant difference between the average reported level of self-satisfaction from the treatment group ($M=4.11$, $SD=0.92$) than the control group ($M=4.0$, $SD=1$); $t(16)=0.24$, $p=0.81$.

In the additional comments section of the post-presentation questionnaire five participants from the control group claimed that their level of satisfaction of the presentation depended on the amount of questions and usefulness of feedback given by the audience. One participant from this group commented about the difficulty to give a presentation in English, and another one commented to still be shaky after the presentation. Two participants of the control group did not have extra comments.

Regarding the additional comments from participants of the treatment group, four participants commented that overall it was good to use *the Booth*. One of them provided also some ideas for extra exercises e.g. warming up the voice, and doing different warming up movements and postures. Two participants from the treatment group commented to feel confident once the presentation started, and remained confident even when some struggles appeared. One participant reported to feel confident during the presentation, and asked whether it is possible to know if this was the result of the placebo effect or the intervention. One participant remarked not feeling fit on that day. Finally one last participant did not leave any additional comments.

Discussion

The first step of the study allowed us to give an answer to our research questions RQ1a and RQ1b. RQ1a refers to usability issues that could obstruct the use of *the Booth*. After conducting the tests for this first step we could discard the existence of significant usability issues with the current version of *the Booth*. Results from this step also show that the use of *the Booth* positively influenced the self-reported emotional state of participants, by reducing the reported negative emotions and increasing the reported positive ones. We acknowledge that there might be differences between the self-reported emotional state and actual emotional state of participant, thus we can not determine to which degree *the Booth* helped participants to improve their emotional state. Nevertheless, with this limitation we consider that this study still provides us with a satisfactory answer to RQ1b, which inquiries whether the use of *the Booth* has a positive effect in the emotional state of users.

The answers of these two research questions, allowed us to proceed to the second step of the study and explore whether the use of *the Booth* could help learners to acquire a more resourceful and powerful emotional state before a foreseeable stressful situation, such as giving a public presentation.

When looking at the self-reported emotions from the pre-questionnaires it is possible to find differences between participants from the two steps of the study. On the one hand during the first step of the study the most reported emotion was feeling neutral whereas feeling anxious was hardly reported. On the other hand during the second step of the study feeling anxious was one of the most reported emotions whereas feeling neutral was hardly reported. Nevertheless, results regarding the self-reported emotions after using *the Booth* remained similar for both steps of the study, showing through the self-report that the Booth stimulated many of the participants to feel energetic, enthusiastic, happy and joyful. This suggests that the intervention of *the Booth* works in normal conditions as well as in mildly stressful conditions that alter the regular emotional state of learners.

Results from this second step of the study also indicate that the use of *the Booth* results in a reduction of self-reported emotions that can hinder cognitive capabilities and academic performance such as anxiety, nervousness, and stress (Cassady, & Johnson, 2002). When making a comparison between the self-reported emotions from participants who followed the common practice of studying their slides before their presentation, results show no indication that this practice has an influence in the self-reported emotional state of the participants. This is in contrast with the results obtained by the participants using *the Booth*, where participants reported a decrement in the amount of negative emotions and an increment the number of positive ones, such as joy, happiness, enthusiasm, etc. For the particular case of preparing for a presentation, this feature can be quite crucial since emotions are contagious and good presenters use their emotions to engage with the audience (Gallo, 2014).

From the extra comments made by the participants after their presentation, it is interesting to observe the general approval of using *the Booth*, and that one third of the participants mentioned how confident they felt during the presentation. It is worth noticing that additional comments are not necessarily findings, they provide us with insights but we cannot draw conclusions out of them.

RQ2 inquires whether the use of *the Booth* helps people to acquire a resourceful and powerful emotional state that allows them to perform well during a presentation. Results from this study provided us with a partial answer to this question. First we encounter similarities between the self-reported emotional states after using *the Booth* for both steps of the study, showing a significant increment in the reported positive emotions and a significant decrement of the negative ones. Second: when looking at the comparison of the self-reported emotions between the group that studied the slides and the group that used *the Booth,* results from the post-questionnaire revealed some differences. In the case of the negative emotions the group using *the Booth* reported having less negative emotions than the group studying the slides. This difference between groups displays a non-significant trend. In the case of the positive emotions the group using *the Booth* reported having more positive emotions than the group that studied the slides. This observed difference between groups is marginally significant. The comparison of the self-reported emotions, before and after using *the Booth*, and the comparison between the self-reported emotions between the treatment and control group indicate that the use of *the Booth* helps to elicit a positive emotional state in users. Still this acquired emotional state only provides a partial answer to our RQ2. To give a full answer to this research question it is important to identify whether this acquired emotional and mental state leads to performing well as presenters. This point illustrates a limitation in our study. In order to determine whether participants performed well, it is required to have an objective method to measure the performance of the participants. There are rubrics (Schreiber et al., 2012) and questionnaires (Schneider et al., 2016b) designed to measure the speaker's performance. However, there is a wide variety in public speaking experience among speakers. Hence, any measurable difference in the performance among them is likely to be attributed to their experience as speakers rather than to the intervention with *the Booth*. Obtaining the baseline level of performance for each of the participants would provide a solution to this challenge, by comparing their baseline against their performance after the treatment. Nonetheless, obtaining this baseline was not a feasible task to achieve for this study.

To gain some insights on the effects that the use *the Booth* has on the participants' performance, we inquired the self-satisfaction of participants regarding their presentation. The scores from the self-satisfaction questionnaire are fairly similar between participants that prepared with *the Booth* and participants that studied their slides, no noteworthy differences were observed between groups.

The amount of participants for this second step of the study presents another limitation. It allowed us to observed that the use of *the Booth* had a positive effect in the self-reported emotional state of the participants, nonetheless it did not allowed us to observe any effects regarding the use of *the Booth* and the level of self-satisfaction of the performed presentations. Moreover it does not allow us to determine if the emotional state induced by the use of *the Booth* helps users to perform well as presenters.

Conclusion and Future Work

In this study we evaluated a tool called *the Booth*, which is designed to help learners to prepare emotionally for expected stressful events and challenges. Results from the two-steps evaluation regarding the use of *the Booth* allow us to draw the following conclusions:

- Using *the Booth* resulted in an enjoyable experience for participants.
- As a standalone activity the use of *the Booth* showed to have a positive influence in the self-reported emotional state of users. In general interacting with *the Booth* helps users to feel more positive emotions, while decreasing the feeling of negative ones.
- *The Booth* has shown to have a positive impact in the self-reported emotional state of users even in emotionally charged situations, such as preparing for an oral presentation. Its use had a constructive effect on positive emotions including confidence, powerfulness and enthusiasm, while reducing negative emotions such as anxiety, nervousness and stress.

As discussed in the previous section, in this study we could not observe whether the use of *the Booth* helps users to perform better on emotionally charged events. Therefore, as future work, we plan to continue this research and investigate the effects that the induced emotional state produced by *the Booth* has on learners' performance. In order to test this effect in performance, we anticipate the possibility to shift our focus, and do not limit our study to oral presentations. Oral and written examinations, negotiations, interviews, sports events, etc. also present good scenarios where we can study the effects in performance driven by the use of *the Booth*.

We currently suspect that the positive results obtained in this study can be explained by the presented psychological practices and techniques behind the exercises in combination with the novelty of *the Booth*. Therefore, to continue with the improvement of the *Booth*, we plan to design and develop new lectures. Instead of expanding in time, we plan to rotate the lectures, so that using *the Booth* remains fresh for recurrent learners while keeping it between three to eight minutes long. The purpose of these improvements is to study the reusability of *the Booth*, exploring the effects on the emotional states of users after multiple exposures to *the Booth*.

Events such as job interviews, negotiations, exams, presentations, etc. can have a big impact in the life of learners. Preparing for this type of events requires from learners to prepare content wise as well as to prepare a supportive mindset that will allow them to perform well during them. As shown in this study *the Booth* is able to help learners to obtain a powerful emotional state by reducing negative emotions and increasing the positive ones. This induced emotional state can serve as the mindset preparation that helps learners to perform well.

Chapter IX

A Field Study of Technological Tutors Teaching Teenagers to Talk in Public

As shown in the studies of the previous chapters, the PT and *the Booth* have already shown their potential to support learning. However, for them to have an impact in education, they first need to be adopted in educational programs. The adoption of new technologies has its barriers. Without addressing these barriers the adoption is likely to fail. Research on the use of new technologies conducted on site can help to identify their opportunities and limitations, thus helping to come up with strategies to address their possible adoption barriers. This chapter describes a field study that explores the use of the PT and *the Booth* with first year secondary school students following a course on oral communication. Results of the study point out weaknesses, limitations and educational opportunities for both of the prototypes.

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Introduction

We live in an era where Information and Communication Technology (ICT) is becoming pervasive in most areas of our life. Educational institutions and ministries in education have identified this phenomena pointing out the urgency to modernize education through the use ICT, and prepare students to strive in the newly created ICT environments (Kennisnet, 2015). One key advantage identified for the introduction of ICT in education is the opportunity to personalize the education (Kennisnet, 2016). Human teachers manage to provide effective, individualized teaching to small groups from two to four students (Lipsey et al., 2012). With larger groups it is not feasible for them to constantly adapt their instruction, exercises and provide them with formative feedback that allows them to improve (Berlanga, Van Rosmalen, Boshuizen, & Sloep, 2012). Examples of more scalable personalization are found in intelligent tutor systems that provide students with content and exercises based on their performance (Farrell, Anderson & Reiser, 1984; Aleven, Mclaren, Roll & Koedinger, 2006; Elnajjar & Naser, 2017). Computer systems can also adapt themselves in order to provide a better fit to each student particular preference (Brusilovsky, & Maybury, 2002; Wilson & Scott, 2017).

However, adopting new ICT in educational institutions has its barriers; perceptions of high levels of risk, together with a reluctance to take risks, can be a major impediment to change (Le Fevre, 2014). Barriers in the adoption of ICT usually present themselves in the following scenarios: the use of the new technology does not match with the curriculum of the courses (Jones, 2004; Klopfer, Osterweil & Salen, 2009; Vrasidas, 2015), the pedagogical aspects of using the new technology are missing (Hadley & Sheingold, 1993; Jones, 2004), teaching staff do not have enough time available to prepare the required material for the use of the new technology (Jones, 2004; Vrasidas, 2015). Moreover, teaching staff is likely to present resistance to the adoption of new ICT (Brummelhuis, Kramer, Post& Zintel, 2015), particularly when teachers do not feel confident enough to operate the new technologies and are unsure on how to face technical faults during lessons (Hadley & Sheingold, 1993; Jones, 2004; Robinson, 2011). Failing to address adoption barriers can impede the effective implementation of new ICT even when the ICT itself has proven to be effective (Ertmer, 1999; Klein & Ralls, 1995). Therefore, Kennisnet, a public organization for education and ICT in the Netherlands recommends to strategize the adoption of emerging ICT. Kennisnet suggests adopting new technologies once their opportunities and weaknesses are identified, thus their impact in education becomes clear (Kennisnet, 2016).

Sensor technologies for education due to their early developmental stage have not spread yet in formal educational practices, nonetheless have shown potential to provide support for many different learning scenarios (Schneider et al., 2015a). One of these scenarios is public speaking. In this particular learning scenario research has already shown promising results under controlled conditions (Barmaki & Hughes, 2015; Dermody, & Sutherland, 2016; Schneider et al., 2016a). To contribute with the adequately introduction of these types of prototypes to current educational practices it is important to address their possible adoption barriers. For that it is necessary to conduct field studies to recognize in context the variables influencing their use and therewith their educational opportunities, limitations and weaknesses.

The study in this article describes an exploratory four weeks long field research conducted in Grotius College. Grotius College is a secondary school that belongs to LVO Parkstad. LVO Parkstad consists of a group of five secondary schools located in the south of the Netherlands. The schools work close together in order to achieve common educational goals, such as improving the education of their students through the adoption of ICT. During this study, first year secondary school students following a course in oral communication used two different sensor-based prototypes: the Presentation Trainer (PT) and *the Booth*. Both prototypes provide different type of support to learners who want to improve their public speaking skills and have been researched in controlled conditions. The PT supports learners with the practice of their nonverbal communication skills, and *the Booth* supports learners with the preparation of a supportive mindset to give presentations. This article contributes to the state-of-the-art of sensor-based prototypes designed to support the development of public speaking skills, by presenting the identified weaknesses, constrains and opportunities of using the PT and *the Booth* in the setting of a first year secondary school oral communication course.

LVO Parkstad approach towards ICT

For LVO Parkstad ICT is the means to provide better education and not the purpose. For example in recent years "personalization and differentiation" have been important concepts introduced to the school plan, therefore ICT coordinators investigated how ICT can be used to support "personalization and differentiation" and developed the ICT plan accordingly.

Almost a decade ago LVO Parkstad took a big step in the adoption of ICT with the introduction of digital boards to their schools. With the introduction of these boards teachers and publishers started to create digital content, helping students to visualize different concepts and items such as historical scenarios and mathematical figures. The next big step after the adoption of digital boards was to provide teachers and later on students with a mobile computer, such as iPads. Currently the schools provide these iPads as a loan to the students. One of the schools also is equipped with an "Inventorium" room where students and teachers can use some latest gadgets such as Occulus rift and 3d printers.

For the adoption of ICT, LVO Parkstad creates ICT plans that fit with the school plans. Eight years ago, LVO Parkstad used to have five years long plans regarding their approach towards ICT. The five year long plan has now been reduced to a three-year plan.

It is crucial for ICT plans to fit inside of the financial budgets, and to support the adopted ICT benefits for students and teachers. Therefore every school has several people conducting research of various technologies available on the market. Research does not end once the technology has been adopted, it is important for LVO Parkstad to investigate whether the adopted technology had the desired effects. One example is a study (Bröcheler, 2014) that investigated how teachers used iPads in the classroom, and how the appropriate use of them resulted in better grades for students following history and German courses. Currently LVO Parkstad collaborates with various universities in ICT related research projects. An example is the Viewbrics project (www.viewbrics.nl), which explores how video-enhanced-rubrics can improve the quality of feedback that a learner receives from peers and teachers (Ackermans, Rusman, Brand-Gruwel, & Specht, 2016).

Researched Prototypes

In this study we explored the use of the PT and *the Booth*. Both sensor-based prototypes are designed to present different type of support to learners who want to develop basic public speaking skills, which nowadays are considered to be a core competence for educated professionals (Campbell, et al., 2001; Hinton & Kramer, 1998; Morreale & Pearson, 2008; Parvis, 2001; Smith & Sodano, 2011).

The PT. Practice and feedback are key components for the development of public speaking skills (Van Ginkel et al., 2015), with the PT learners can practice their presentations while receiving feedback regarding their nonverbal communication. During a practice exercise, the PT captures the learner's nonverbal communication with the use of the Microsoft Kinect V2[16] sensor. In real-time, it first processes the tracked nonverbal behaviors in order to identify mistakes regarding the learner's Posture, Voice Volume, Use of Gestures, Facial Expression, Use of Pauses, Phonetic Pauses (hmmm, ahms, ehms, etc.), and not being grounded to the floor (Dancing). The PT then analyzes the current identified mistakes and selects a single corrective feedback instruction to be presented to the learner (Schneider et al., 2016b) (see Figure 9.1).

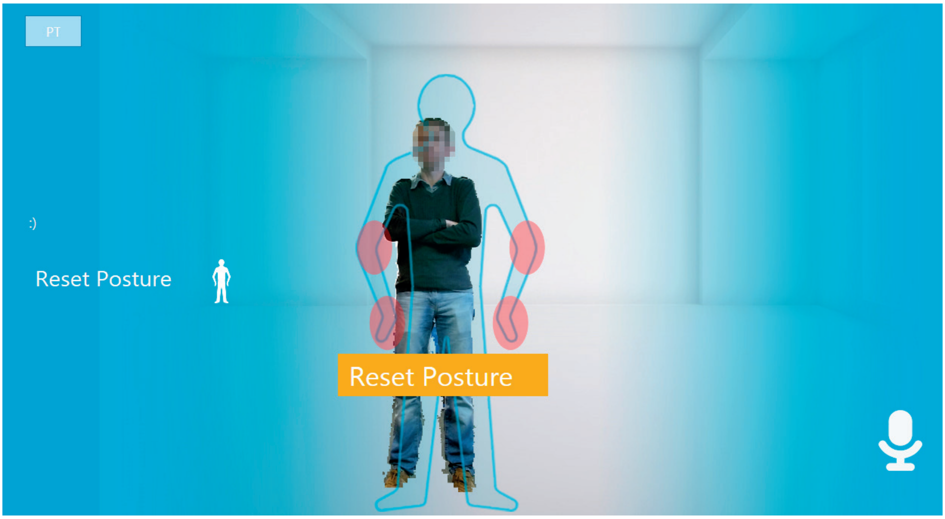

Figure 9.12 PT displaying feedback regarding the learner's posture.

[16] https://developer.microsoft.com/en-us/windows/kinect/develop

After the practice exercise, the PT presents the learner with a module for self-reflection. This module consists of four reports: Pauses, Gestures, Posture and General report (See Figure 9.2). These reports present the learner with events that were captured during the practice exercise and ask the learner to reflect about these events (Schneider et al., 2017).

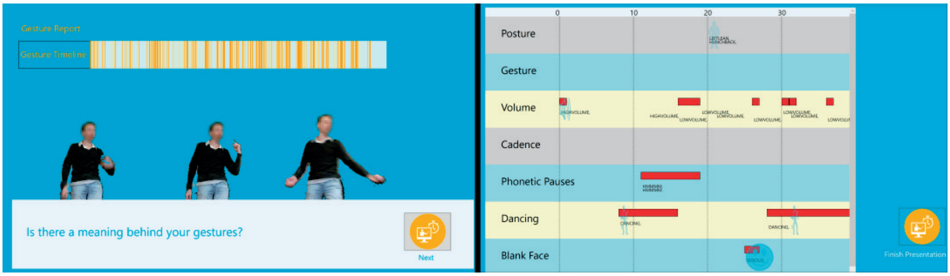

Figure 9.2 Left: Gesture report, showing three different gestures captured and asking the user to reflect about them. Right: General report showing all the events captured by the PT.

The Booth. Speech anxiety is one of the most common problems in public speaking (McCroskey, Ralph & Barrick, 1970). When speakers get nervous, their nervous energy usually results in symptoms that undermine their performance (Grice, Skinner & Mansson, 2016). *The Booth* is a multimodal prototype designed to support the learner to prepare emotionally for a foreseen stressful event, such as giving an oral presentation. The support of *the Booth* is based on the theory of William James stating that actions are the ones guiding our feelings (James, 1890). This theory gave birth to several psychological techniques have been designed to positively influence the emotional state of subjects (Wiseman, 2012) allowing them to have full access to executive functions such as task flexibility, attention control, reasoning, etc. (Derakshan, & Eysenck, 2009). *The Booth* makes use of some of these psychological techniques guiding the learner through five lectures (see Figure 9.3). The five lectures follow a narrative where the learner creates and embodies her own superhero persona (Schneider et al., 2016c).

Figure 9.3 The Booth: From left to right the figure shows a sequence of screen shots displaying the three steps of the Posture lecture.

Purpose

In this study we tested the PT and the Booth following an exploratory research approach (Shields & Rangarajan, 2013). The main purpose of this study is to identify weaknesses and educational opportunities of these tools, exploring technical, logistical and usability requirements for the adoption of these tools in secondary schools, so that students can benefit from their use. To focus our research, we divided this main purpose in the following objectives:

Objective 1: The first objective is to explore the reception that secondary school students give to the PT by observing their interactions with the PT and inquiring about their user experience.

Objective 2: The second objective of this study is to investigate whether practicing with the PT has similar effects in secondary school students that are not familiar yet with giving presentations. In previous studies conducted with adults that are familiar with giving presentations, it has been shown that participants were able to correctly interpret the feedback of the PT, adapt their behavior and show some improvement throughout their practice exercises (Schneider et al., 2016a).

Objective 3: The third objective of this study is to investigate the retention effects of using the PT two weeks after the first practice exercises. Previous studies with the PT only investigated the effects of its use in consecutive practice exercises executed practically without any delay among them (Schneider et al., 2016a; Schneider et al., 2016b; Schneider et al., 2017b), medium and long terms effects has not been tested.

Objective 4: The fourth objective of this study is to explore whether presenting to peers is a scenario where the preparation of a supportive mindset is important, and investigate whether a tool such as *the Booth* can help with this mindset preparation. Research suggest that in order to improve performance at some point the learner should stop preparing content and start preparing a supportive mindset (Raman, Chadee, Roxas, & Michailova, 2013; Cuddy, 2016)

Objective 5: The fifth objective of this study is to explore the current status of the PT and *the Booth* as standalone educational applications able to provide practical support to learners in real world situations. This should help to identify the educational opportunities, current limitations, and implications of using these tools in a real world scenario; since at their current state the PT and *the Booth* are just research prototypes that help researchers to gather data.

Method

Study Context

The study was conducted in the context of a course on oral communication for first year secondary school students (EQF level 2). The course consisted on five weekly lectures of 90 minutes each. A total of 50 students were grouped together in one classroom in order take part of the course. The students were between 12 and 13 years old.

It was their first introduction to oral communication and presentation skills. Twenty-four students (12 females and 12 males) were randomly selected to participate in the study. Parents, teachers, and students provided consent in order to take part of it.

Study Procedure

The study started in the second week of the course and was conducted during the time of the lectures. The study consisted of two different sessions: a training session and a preparation-presentation session. Table 9.1 displays a sketch of the study procedure. The training session consisted of:

- A three minutes introductory lecture where the experimenter explained the students how to use their nonverbal communication during a presentation, and how to interpret the feedback of the PT.
- Two practice exercises with the PT. During these practice exercises each participant had to practice a presentation, where the participant introduced herself and talk about her family, hobbies, pets, etc. while receiving feedback from the PT. The practiced presentations had a maximum length of 65 seconds. After delivering the presentation, each participant went through the reports of the self-reflection module from the PT.

The training sessions took part during the first two weeks of the study. Students arrived in groups of three to the training sessions. After practicing two times with the PT, participants filled in a user experience questionnaire. Once all members of a group finished their two practice exercises, they returned to their classroom and the following group arrived. Eight groups of three students each took part in the training sessions.

The preparation-presentation sessions took part during the third and fourth week of the study. For these sessions, participants also arrived in groups of three students. These preparation-presentation sessions had two different set-ups. The first set-up (PT set-up) consisted on having a preparation (practice) exercise with the PT and then delivering the presentation to the other members of the group. The second set-up (*Booth* set-up) consisted on first using *the Booth*, and then delivering the presentation to the other members of the group.

The preparation and delivered presentation had the same format as the ones practiced during the training sessions (a maximum 65 seconds long presentation about family, hobbies, etc.). After delivering the presentation, the participant filled in a questionnaire to self-assess her presentation and her emotional state. The other two members of the grouped played as juries and assessed the presentation of their peer. Once each member of the group gave a presentation the group of students returned to their classroom and the following group arrived to the study. For reasons unknown two groups of students never arrived to the preparation-presentation session, one group from the third week and another one from the fourth. Therefore only a total of six groups of three students each took part on the preparation-presentation sessions. Four groups followed the PT set-up and two groups followed the *Booth* set-up.

Table 9.1 Sketch of the of the study procedure.

Training session (n=24)	
Introductory Lecture	
PT Practice Exercise (2x)	
Preparation-Presentation session	
PT set-up (n=12)	*Booth* set-up (n=6)
Practice PT (1x)	*The Booth* (1x)
Presentation	

Apparatus and Material

To evaluate the students' reception of practicing with the PT we used a user-experience questionnaire. Through this questionnaire we inquired: motivation to use the PT again, learning perception, comparison between using the PT and learning in traditional classroom setting, novelty of the PT, brief description of what they learned while using the PT, and additional comments.

We used the logged files created by the PT to measure the participants' performance for the different practice exercises and also during the presentation that participants gave to the peers. For this last session the PT was used as a measuring device, participants could not see its feedback. These logged files contained all the events captured by the PT. The experimenter also used a score sheet to log the occurrences when the participants deliberately used a pause, specific gesture, or specific posture.

Peers scored the presentation given during the preparation-presentation section based on how much they liked it in general, how much they liked its delivery and how much did they liked its content. Participants self assessed their presentations using the same criteria. To evaluate the emotional state of the participants during the presentation, participants filled in the Positive and Negative Affect Schedule (PANAS) (Watson, Clark & Tellegan, 1988).

During the sessions the experimenter also took notes in order to get a better understanding of the events that happened during the study.

Results

Training session: Reception of the PT

When asking participants if they have used an application similar to the PT in the past, results show the PT to be a very novel application for participants. 71% reported to never have used a similar application, 21% reported that "Maybe", and 8% reported "yes". In terms of motivation to use the PT again, participants on average reported a score of 7.3 (SD =1.88) (a ten-point scale with one being not motivated at all and ten being very motivated). This indicates that on average participants felt motivated to use the PT in the future. In terms of learning perception participants reported an average score of 8.2 (SD = 1.22) (ten-point scale one meaning not having learned anything at all and ten having learned a lot). This score suggests that on average participants perceived to learn something while using the PT. When comparing the use of the PT with traditional classroom learning, participants scored on average the use of the PT a bit better than learning in a classroom setting providing an average score of 6.9 (SD = 1.94) (one being much worse than traditional classroom and ten being much better than classroom). Figure 9.4 shows the distribution of the scores.

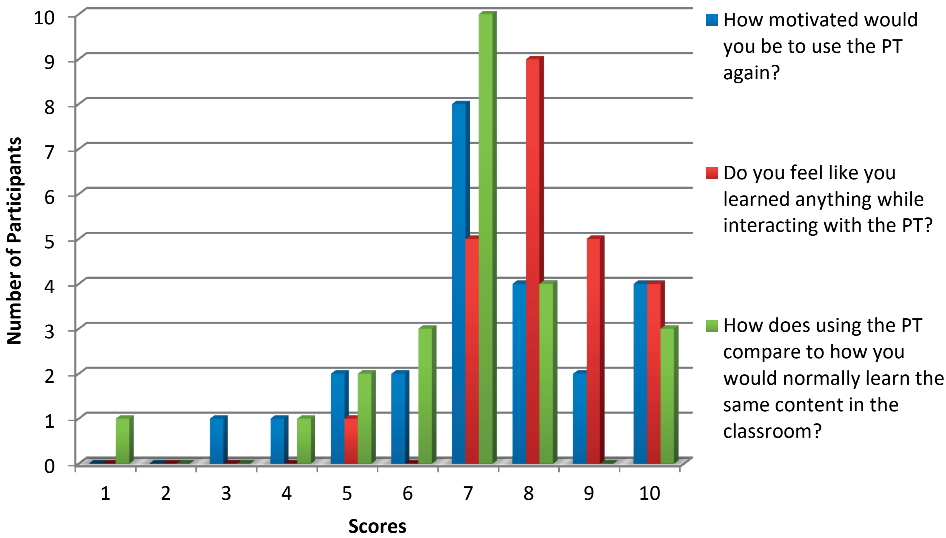

Figure 9.4 Shows the amount of users that give a particular score to the PT in terms of motivation, learning perception, and the comparison between using the PT and learning in the traditional classroom setting.

Table 9.2 displays what participants stated to have learned while interacting with the PT. Learning how to stand during a presentation was the most common answer reported by five participants, followed by learning how to present in general stated by four of them. Three participants reported to not have learned anything specific while using it.

Table 9.2 Participants report on what they learned while interacting with the PT.

Aspect	# Participants	Example comment
Posture	5	“The posture”
How to present in general	4	“How to present myself better”
Pauses	3	“Take rest to talk”
Nothing specific	3	“Nothing special really”
Standing still	2	“That I have to stand still”
Speak louder	2	“Speak louder”
Gestures	2	“That I have to move more with my hands”
Phonetic pauses	2	“Use less hmms”
Prepare content	1	“In advance you must think about what you are going to say”

Five out of the 24 participants provided answers to the extra comment section. Three participants reported to like using the PT, as one of them said: "I found a nice test to do and will definitely use it because it helps me". Two participants mentioned that it would be better to use the PT when being alone. This aligns with the notes of the experimenter pointing out that there were too many outside distractions during the practice exercises. Many of these distractions came from the peers that were waiting for their turn to practice. In part of the sessions during the presentation exercises peers started laughing, or shouted comments sometimes with the purpose to help and sometimes with the purpose to distract the colleague that was practicing. In many occasions, due to these distractions, the student that was practicing engaged in a dialogue in the middle of the practice exercise. Other distractions were the school's end-of-class-session signals, which additionally caused sounds connected to all students moving into the school corridors.

Training session: PT scores

We analyzed the performance of the participants for both of the practice exercises using the PT's logged files. These files contain the starting and ending timestamp for all the events (at its current version "mistakes") captured by the PT. We evaluated the impact of these "mistakes" by calculating the percentage of time displayed by them during the practice exercises (pTM). The pTM value for each mistake gores from 0 to 1; 0 indicating that the mistake was not identified at all during the practice exercise, and 1 indicating that the mistake was identified throughout the whole practice exercise. The average pTM values for all tracked mistakes are displayed in Table 3. Results indicate that on average participants improved on all areas with the exception of Dancing, where on average they performed a bit worse. The area displaying the biggest improvement was the use of Gestures, followed by Posture and Volume. We conducted a paired t-test to compare the mean from the total pTM between the two practice exercises. Participants on the first practice exercise had a higher pTM score ($M=1.128$, $SD=0.67$) than on the second practice exercise ($M=0.890$, $SD=0.50$); $t(23)=2.66$, $p=0.014$. These results show a significant improvement in the participants' pTM performance between sessions.

During the practice exercises the experimenter used a score sheet to note down the cases when a participant deliberately did give a pause (pausing without receiving feedback of the PT), deliberately used an iconic gesture, or deliberately used a special posture. During the first practice exercise the experimenter identified two participants doing a deliberate pause in one occasion each. For the second practice exercise the experimenter identified seven participants doing a deliberate pause. Six of them deliberately stopped speaking one time, and one participant deliberately paused two times. In the case of deliberate gestures the experimenter identified two participants using a deliberate gesture once during the first practice exercise. In both cases the deliberate gesture was waving the hand to express a greeting. On the second practice exercise the experimenter identified nine participants using a deliberate gesture. Seven of them presented one deliberate gesture, one of them presented two deliberate gestures, and one participant presented six deliberate gestures during their second practice exercise. The most common deliberate gestures identified were: waving the hand to greet, and raising one hand up while the presenter talked about her older sister or brother. No deliberate posture was identified in any of the sessions. These observations suggest that some participants started to understand the principle of using gestures and pauses to support their communication.

The experimenter also observed that participants had some difficulty on using their nonverbal communication with purpose. Their movements and speech did not seem fluent, even when they seem to put a lot of effort in delivering a good performance. When going through the self-reflection modules many participants out-loud commented that they did not use pauses with purpose, that their posture is not reflecting the attitude that they want to project, and/or that they were not satisfied with their use of gestures. When the self-reflection module presented participants with questions asking them to reflect on how to improve their use of pauses, gestures and posture, most participants turn their gaze to the experimenter looking confused and expecting to get an answer from him. In one occasion after seeing the disappointment in the faces of the participants, at the end of the two practice exercises, the experimenter told the participants of one of the groups: "Two of you talked about your dogs during the presentation, how big are your dogs? You can use your gestures to show that and help people imagine how does your dog look like". This comment had an effect on two of the participants' performance two weeks later.

Preparation-presentation session

We used the logged files of the PT to analyze the performance of the participants during the preparation session with the PT. During this session on average participants performed worse than during the first and second practice exercise of the training sessions. The average total pTM for this preparation session was of 1.274 in comparison to 1.128 displayed in the first practice exercise. The biggest difference encounter between these two sessions was in posture with an average Posture pTM of 0.268 during the preparation session and an average Posture pTM of 0.155 during the first practice exercise. Table 9.3 displays the average pTM for all sessions.

Table 9.3 PT's mean scores for practice, preparation and presentation sessions

	Posture pTM	Volume pTM	Pauses pTM	Blank F. pTM	Gestures pTM	Dancing pTM	Phonetic P. pTM	Total pTM
Practice 1	0,155 (0.23)	0,262 (0.15)	0,251 (0.19)	0,056 (0.15)	0,319 (0.31)	0,065 (0.14)	0,019 (0.01)	**1,128** **(0.67)**
Practice 2	0,094 (0.17)	0,217 (0.13)	0,246 (0.16)	0,017 (0.05)	0,210 (0.26)	0,090 (0.14)	0,016 (0.01)	**0,890** **(0.50)**
Preparation	0,268 (0.30)	0,257 (0.17)	0,296 (0.18)	0,000 (0.0)	0,314 (0.27)	0,126 (0.22)	0,013 (0.01)	**1,274** **(0.63)**
Presentation	0,121 (0.22)	0,376 (0.23)	0,343 (0.21)	0,026 (0.1)	0,321 (0.33)	0,176 (0.19)	0,019 (0.01)	**1,383** **(0.74)**

The experimenter did not observe any deliberate pause or posture during the preparation sessions. The experimenter identified on two occurrences the execution of deliberate gestures. Two participants used their hands to show the size of their dog.

After the preparation session either with the PT or the Booth participants gave a presentation to their peers. For these presentations, the PT was used to measure the performance of the participants; participants had no access to its feedback. Results from the from the pTM scores grouped by the participants who prepared with the PT and participants who prepared with *the Booth* are displayed in Table 9.4. Results show that in terms of the pTM scores, on average participants who prepared with the PT performed slightly better than participants who prepared with *the Booth*. By using a t-test we could identify that these measured differences were not significant (t(8)=1.24, p=0.12).

During these presentations the Experimenter was able to identify one deliberate pause from a participant that prepared with the PT, and the same two deliberate gestures as identified during the preparation.

Table 9.4 PT's mean scores for the final presentations grouped by the type of preparation followed by the participants (PT vs Booth)

	Posture pTM	Volume pTM	Pauses pTM	Blank pTM	Gestures pTM	Dancing pTM	Phonetic P. pTM	Total pTM
PT	0.150 (0.26)	0.321 (0.15)	0.298 (0.18)	0,039 (0.12)	0.301 (0.32)	0.090 (0.10)	0.020 (0.02)	**1.219 (0.66)**
Booth	0.063 (0.10)	0.486 (0.34)	0.433 (0.26)	0 (0)	0.363 (0.38)	0.349 (0.23)	0.018 (0.02)	**1.711 (0.85)**

The presentations were evaluated by the peers and also self-assessed by the participants. Results from these evaluations are displayed in Table 9.5. Results show that in all assessed areas participants who prepared using the Booth received higher scores. We used t-tests to compare the scores from the peer-assessments between both groups. Results from the t-tests show marginally significant differences for the assessments of general aspects of the presentations (t(16)=2.07, p=0.055), significant differences for the delivery of the presentations (t(9)=3.45, p=0.007), and non significant trends for the content of the presentations (t(6)=0.79, p=0.46). The self-assessment group that used *the Booth* also scored their own performance higher than the group that used the PT. We compared the self-assessment scores between groups using t-tests. Results from the t-tests show significant differences for general aspects of the presentation (t(10)=3.24, p=0.009), delivery (t(14)=2.66, p=0.019), and content (t(15)=2.93, p=0.01).

Table 9.5 Peer and self assessment mean scores for the final presentation grouped by the type of preparation followed by the participants

PT		General	Delivery	Content
	Peer-assessment	6.58	6.81	6.81
		(1.65)	(0.95)	(1.21)
	Self-assessment	6.25	6.33	6.38
		(1.22)	(1.73)	(1.80)
Booth	Peer-assessment	7.71	8.54	7.63
		(0.64)	(1.02)	(2.39)
	Self-assessment	8.17	8.17	8.33
		(1.17)	(1.17)	(1.03)

After giving the presentation participants were asked to fill in a PANAS questionnaire (Watson, et al., 1988) inquiring about how they felt during the presentation. In this questionnaire there is a list of 20 different emotions, ten positive and ten negative, and the participant has to rate in a scale from 1 to 5 to what extent they felt that emotion. Adding the scores of the positive emotions gives an indication of the positive affective state of the participants, and adding the negative provides an indication of the negative affective state. PANAS also provides with mean scores for the positive and negative affects that can be used as baseline. The mean momentary score for positive affect is 29.7 and the mean momentary score for negative affect is 14.8.

We used t-tests to compare the means of the reported positive and negative affects between the group that prepared with the PT and the group that prepared with *the Booth*. Regarding the positive emotions, results from the t-test show that participants who used *the Booth* reported to have significant more positive emotions (M=29.17, SD=3.31) than participants that used the PT (M=18.75, SD=6.76); t(16)=4.39, p=0.00046. For *the Booth* group, scores are similar to the baseline, for the PT group scores are below the baseline. Regarding the negative emotions a non-significant trend was observed. Participants who used the PT reported more negative emotions (M=24.5, SD=8.02) than participants that used *the Booth* (M=18.67, SD= 8.98); t(9)=1.46, p=0.178. In this case both groups reported to higher scores than the base-line.

The experimenter observed that participants from the groups that prepared with the *Booth* had the tendency to become more impatient, and difficult to control. They did not take the preparation-presentation session as seriously as the groups that pre-pared with the PT.

Finally, the experimenter noted down that even when they were asked to, none of the participants for any of the sessions prepared the content of their presentations; they all improvised their presentations while practicing, preparing and presenting.

Discussion

Studying the use of the PT and *the Booth* in a secondary school provided us with numerous formative insights. In general the PT got a good reception by participants from this study, providing a satisfactory answer to *Objective* 1 of this study. After using it during the practice exercises they became motivated to use the PT in the future and reported to have learned different aspects on how to present.

Objective 2 investigates whether secondary school students with no previous experience in giving presentations can benefit by using of the PT. The practice exercises provided us with indications suggesting so. One of these indications is in the logged data from the PT; this data shows that participants significantly improved their performance throughout the practice exercises. Another indication suggesting that participants learned while using the PT is the difference in the amount of deliberate pauses and gestures identified by the experimenter that considerably increased during the second practice exercise. It is important to notice that participants in this study during the practice exercise performed worse than participants from previous studies conducted with a similar version of the PT (Schneider et al, 2017). In the previous study the average total pTM for the first practice exercise was 0.739 and 0.451 for the second, in contrast with this study where the average total pTM for the first practice exercise was 1.128 and 0.89 for the second. There are several factors that can explain these observable differences. We consider that the experience of the presenters is a major factor. In the previous study participants had significant more experience in giving presentations and already had a basic understanding of the principles behind nonverbal communication. In contrast participants in this study had no experience at all. In this study participants showed also a lack of understanding behind the principles of nonverbal communication while using the self-reflection module of the PT. Participants identified that there was something wrong but were clueless on how to improve it. The example of the “dog gesture” shows that once participants are told what they can do they immediately are able to do it. However, without telling them they have no clue. Other factors explaining the observable differences between this study and the previous one are the amount of external distractions that occurred during the practice exercises, and the fact that participants were not able to practice while being alone in one quiet room. Finally in the previous study participants prepared the content of the presentation before going to the practice exercises; participants in this study improvised it.

Objective 3 of this study investigates the retention effects of using the PT. To give an answer to this objective we examined whether the improvements observed during the training sessions could also be observed during the preparation-presentation sessions conducted two weeks later. Results from this study show that this was not the case. Based on the logged files of the PT and on the deliberate behaviors identified by the experimenter, on average the performance of participants during the preparation-presentation sessions was even worse than their performance from the first practice exercise. Our explanation to this observed decrease in performance is the lack of the introductory lecture that was presented during the training sessions, but not during the preparation-presentation sessions.

Objective 4 of this study explores whether the preparation of a supportive mindset is useful for presenting to peers, and identify whether *the Booth* can help students with the acquisition of this mindset. Results from the PANAS questionnaire suggest that giving a presentation to peers is an event that has an effect in the affective state of participants increasing their negative affective scores and decreasing the positive affective ones. Therefore, the preparation of a supportive mindset for these types of events seems suitable. This study provided us with results suggesting that *the Booth* could help with this mindset preparation. A first suggestion comes from the results of the PANAS questionnaire. Answers from this questionnaire show that participants that prepared with *the Booth* tended to have lower scores for negative affect, and significant higher scores for positive affect during the presentations, than participants that prepared with the PT. A second point suggesting that *the Booth* helped participants with their presentations is found on the scores given to the presentations. The presentations of the group that used the Booth to prepared, had higher peer and self-assessment scores than the ones of the group that used the PT. However, it is important to point out that the number of students participating in this study is too small to draw definitive conclusions.

Objective 5 explores the educational opportunities and gaps that need to be overcome so that the PT and *the Booth* could be incorporated to school programs providing practical support to students. *Objective* 2 and *Objective* 4 provide use with the educational opportunities that these tools can offer. The first of these two objectives discusses how participants improved their performance using the PT. The second objective discusses how *the Booth* helped participants to acquire a supportive mindset that helped them to feel better while presenting and about their performance.

A first gap to be addressed comes from the results of this study that show a decrement in performance shown during the preparation-presentation session. This decrement in performance allowed us to identify the relevance of the three minutes introductory lecture that was given to the participants during the training sessions. We identified that this lecture has a direct influence in the participants' performance, and that participants need to be regularly reminded about the aspects communicated in that lecture. As discussed previously, participants in this study did not only lack experience in presenting, they also lacked a basic understanding of the principles behind nonverbal communication. Therefore, we consider that for learners at this level, the use of the PT should be coupled with lectures explaining the principles behind the nonverbal communication for presentations, creating an integrated lesson design where students first receive the lecture and then have chance to practice the concepts of the lecture using the PT.

A second point to be addressed was pointed out while participants where using the self-reflection module. During these interactions it was observed that participants were able to identify that different aspects of their nonverbal communication were not ideal, but did not know how to improve it. In this study we could also observe how two participants remembered a simple example on how to use gestures, and used the same example two weeks later while describing the size and shape of their dogs. Therefore, we consider it important to also include in the self-reflection module of the PT a set of video examples displaying different strategies on how to use pauses, postures and gestures. In alignment with the previously discussed integrated lesson design, the purpose of introducing this set of video examples is to help students gain a better understanding of the principles behind the nonverbal communication for presentations.

We consider it also important to address the limitation concerning the set-up of the PT and *the Booth*. Both applications were designed to be individually used in a private space. Comments of the participants and observations from the experimenter coincide that it would be better to use these applications while being alone without distractions. This is a difficult problem to solve, since practically every space in a school is public. Allocating private spaces for the use of these types of tools might be a challenge.

We also identified logistical constrains that need to be addressed in order to fit the use of these tools in current courses. The time allocated for courses is limited, adding some practice time with the PT, or adding mindset preparation time with *the Booth* during school hours would mean having to skip some course material, which is a common identified barrier for the adoption of new technology in educational institutions (Jones, 2004; Klopfer, Osterweil & Salen, 2009; Vrasidas, 2015). Sacrificing some course material for practical practice time might be worth considering; in case this practical practice time would offer some tangible benefits and results. In the case of using *the Booth* some tangible results, can be obtained through better scores in the different type of assessments received and performed by students. Results from this study already suggest that its use before giving a presentation has a positive influence in peer and self-assessment scores. It is still mandatory to identify whether scores given by teachers' are also positively influenced by the use of *the Booth*.

To obtain tangible benefits and results with the use of the PT we consider essential to improve the PT based on the results obtained in this study. A plan for this improvement is the creation of small self-study course. This self-study should contain small lessons on specific nonverbal communication principles that can be trained with the PT, accompanied with practice exercises using the PT and its improved self-reflection module. An example lesson of the course could contain a lecture explaining the relevance of using pauses complemented by practice exercises where the student has to write down a presentation explaining the relevance of using pauses, and later has to practice the presentation using the PT while focusing on using a big pause every three sentences. One option to introduce a self-study PT course to school courses would be to present the lessons of the self-study course as homework assignments for students. For that we also find it relevant to provide teachers and students with reports of the practice exercises, in order to keep track of the students' improvements. A constraint for this alternative is to provide students with a Kinect V2 sensor to conduct their homework.

This study has some general limitations due to the time and availability constraints of the students. The initial plan was to include all participants in the training sessions and split this group equally over the two preparation=presentations sessions so that we could have a better comparison between the group using the PT and the group using *the Booth*. Unfortunately only 18 students participated in the preparation-presentation session. This small numbers of participants does not allow us to get conclusive results regarding the effects of *the Booth* in terms of peer and self-assessment. We also acknowledge that two practice exercises with the PT is an absolute minimum to study its effects in learners. We expect that by adding more practice exercises, the effects of using the PT would have become more visible. However, due to time constrains the addition of more practice exercises would have resulted in a reduced number of participants. While these limitations presented challenges in getting more convincing summative data, from a formative perspective they illustrate the obstacles that the adoption of tools such as the PT and *the Booth* need to overcome in order to provide students with clear educational opportunities.

Conclusion

In this study first year secondary school students following for their first time in their life a course in how to present to the public, tested the PT and *the Booth*. The conduction of this study helped to identify limitations and weaknesses regarding the use of these tools in a secondary school setting. The main identified weaknesses and limitations concerning the use of the PT and *the Booth* are:

- During the practice exercises conducted on the third and fourth week, the use of the PT without the introductory lecture showed to be too difficult. This issue points out the importance of creating integrated lessons where small lectures explain basic principles of public speaking and afterwards these principles can be practiced with the help of the PT.
- Students were able to identify problems with their nonverbal communication, but presented difficulties on knowing how to correct them. Therefore, the PT should be able to provide users with examples on how to use the nonverbal communication with purpose.
- Using the PT and *the Booth* in a public space with people observing and distracting is not optimal. Thus it is important to provide students with a private space to use them.

Results from this study also revealed some educational opportunities regarding the use of the PT and *the Booth*. The main educational opportunities identified are:

- Students enjoyed practicing with the PT, felt motivated to use it in the future, and perceived its use to be beneficial for learning how to present better.
- Measurements from the practice exercises show a general improvement in the students' performance.
- *The Booth* helped students to feel emotionally better while giving a presentation to their peers, and helped them to feel better about their own performance.

For future work the next step is to discuss the findings of this study with teachers and ICT coordinators. Together with them the aim is to come up with strategies and implementation plans to address the identified weaknesses and limitations regarding the use of the PT and *The Booth* in a secondary school setting. So that science of today becomes the technology that tomorrow will support students with the process of becoming better communicators.

Chapter X

General Discussion

Review of Findings

This dissertation reports on studies conducted with the purpose to explore the use of sensors to support the learning process. It first reports on a literature study investigating a general perspective on how sensor-based applications could be used to support learning. The dissertation continues with a design-based research approach consisting of three complete iterations. These iterations explore the design, development and use of sensor-based prototypes designed to support the development of public speaking skills.

Literature Study

The literature study (Chapter II) consists of a systematic literature review that analyzes the learning support of 82 sensor-based prototypes. In order to get a general overview of the learning support provided by the prototypes, the first part of the analysis consists of exploring the contribution of the prototypes to the cognitive, affective and psychomotor domain of learning (Bloom, Englehart, Furst, Hill & Krathwohl, 1956). Results from this analysis show that sensor-based applications can provide support to the three commonly identified learning domains and can be used for a vast range of learning topics including science, sports and arts, among others. The analysis also shows that hardly any of the prototypes provided support in more than one learning domain. This indicates that the design of most of the sensor-based prototypes did not take in consideration the relevance of creating a comprehensive educational design that merges the three learning domains (Van Merrienboer & Kirschner, 2007). Altogether, the literature study reveals the early state of maturity of the state-of-the-art of sensor-based learning support.

The analysis of the prototypes continued by studying how these prototypes could support the implementation of formative assessment, which is the type of assessment that provides learners with the necessary information that can help them to improve their learning, but is hardly implemented because its implementation leads to a work overload for teachers (Berlanga, Van Rosmalen, Boshuizen, & Sloep, 2012). Results from this analysis showed that sensor-based prototypes could be used to support key aspects of formative assessment such as: knowledge of the subject matter, knowledge of criteria and standards, attitudes towards teaching, skills in setting evaluative skills, self-assessment, and feedback. At the same time, results also revealed several research gaps regarding sensor-based feedback such as:

- The learning effects of the prototypes were hardly ever studied.
- The method used by the prototypes to provide feedback, was hardly ever justified.
- The immediate feedback of the prototypes was limited to the emission of a particular auditory, a visual or a haptic corrective feedback (Mory, 2004) signal.

To sum up the literature study shows a great potential for sensor-based applications to support learning, however sensor-based applications are still not mature enough to be used in formal learning scenarios.

First Iteration

The purpose of this iteration was to come up with an effective immediate feedback mechanism for the Presentation Trainer (PT); a tool designed to support the development of basic nonverbal communication skills for public speaking. It captures, analyzes and provides in real time feedback regarding certain aspects of the user's nonverbal communication such as posture, use of gestures, use of pauses, and voice volume.

Practicing a presentation while paying attention to the feedback of the PT showed to be a complex task for learners. Three evolving versions of the PT were required to finally come up with a feedback mechanism that learners were able to interpret and correctly adapt to. The first version of the PT provides feedback to users with a dashboard consisting of feedback items that work as semaphores changing from green to red whenever a mistake of the user is identified. User tests from this first version (Chapter III) show great enthusiasm from participants towards practicing with the PT for future presentations. However, participants stated the difficulty of paying attention to all the feedback items while practicing at the same time. Moreover, it was observed that participants were not able to adapt their behavior based on the feedback provided by the PT.

The second version of the PT that was improved based on the findings of the first user study contains two modes: an exercise mode and a freestyle mode. The exercise mode guides users through a series of different type of exercises designed to help with the automation of certain behaviors (e.g. talking a bit and returning to a reset posture, talking louder, talking softer, etc.). The freestyle mode works similar to the first version of the PT, however, the visual aspects of the dashboard interface were improved. An enhanced mirror image of the learner was added, highlighting a posture mistake through the skeleton representation of the learner. Instead of balls working as semaphores this new dashboard interface highlights icons displaying two-word instructions on how to correct the mistakes. Results regarding user tests from this version of the PT (Chapter III) show that participants still encounter difficulties to correctly interpret and adapt to the feedback of the PT while practicing a presentation. Therefore a new version of the PT was developed.

This new version of the PT analyzes the behavior of the user and based on this analysis, it provides the user with at maximum of one feedback instruction at a given time. If the user repeats a mistake several times or does not correct the mistake after a predefined period of time, this new version of the PT interrupts the user pointing out the mistake and explaining how to correct it. This version of the PT was tested through a quasi-experimental study (Chapter IV) showing that learners were able to improve their performance based on the feedback provided by the PT.

The studies conducted for this iteration revealed the following findings:

- Before using the PT learners should receive an explanation on how to correctly respond to its feedback.
- A dashboard interface giving feedback in multiple aspects at the same time is not optimal for learning.

- The third version of the PT that provides learners with a maximum of one feedback instruction at a given time helps learners to improve their performance according to machine-measurements, become more aware of their mistakes, and become more self-confident about future performances.

Second Iteration

The previous iteration explored the development of an interface able to provide learners with the type of immediate feedback that helps them to improve their performance. Results from Chapter IV show that the studied version of the PT was already capable to provide this type of feedback, helping students to improve their performance according to the measurements taken from the PT itself. However, evidence that training with the PT leads to better presentations according to human audiences and therefore supports learners in becoming better public speakers is still missing. The objective of this second iteration is to address this gap focusing on the following aspects:

- The assessment and feedback model of the PT: is the assessment and feedback model of the PT in agreement with the view of experts?
- Training with the PT and human assessment: do learners that practice with the PT give better presentations according to their peers?

Chapter V describes a study where expert public speakers and teachers in public speaking were interviewed regarding the nonverbal communication aspects that affect the quality of a presentation and their expert opinion on how a tool such as the PT could be used to support the development of public speaking skills. Results from this study identify 61 ineffective and 70 good nonverbal communication practices that affect the quality of a presentation. The study discusses how the recognition of these practices could be implemented with the use of sensor-based prototypes. Some of these practices can already be recognized and therefore trained with the use of sensor-based applications. This suggests that an application able to provide effective feedback on some of these identified aspects is also able to support learners in becoming better presenters. Interviewed experts pointed out the relevance of always having human tutors to teach public speaking skills and expressed their concern of using a tool such as the PT to substitute them. However, they explained how a tool such as the PT could be excellent for homework assignments and hence improve the quality of public speaking courses. Experts also suggested changing the focus of the PT's feedback so that it supports the raise of awareness in learners instead of just correcting them.

Chapter VI takes a different approach in studying whether practicing with the PT leads to better presentations. It describes a study where participants gave a pitch in front of a human audience before and after practicing with the PT and the human audience assessed both pitches. The assessment of the pitches consisted of scoring general aspects of the pitch and some specific nonverbal behaviors that can be trained using the PT. Previous to the study participants had already received some basic training in public speaking, they had already presented in front of an audience and received

feedback from peers and tutors regarding their presentation skills. Hence, they were not novice presenters.
Results from this study show that participants would like to use a tool such as the PT to practice for future presentations. They acknowledged that the PT's feedback is a good complement to the feedback that peers and tutors can give. Regarding the audience assessment, all the pitches performed after practicing with the PT, received a better score in all the assessed areas than the ones given prior to the practice sessions with the PT.

These results helped to close the research gap exposed in the previous iteration. They show evidence that practicing with the PT leads to observable improvements according to a human audience in addition to the machine-based improvements shown in Chapter IV.

Third iteration

The aim of this third iteration is to continue with the improvement of sensor-based applications designed to support the development of public speaking skills, addressing the following issues:

- Enhancing the PT with self-reflection: Does the newly added self-reflection module of the PT help learners to become aware and improve their performance?
- Mindset preparation with *the Booth*: Can *the Booth* help learners to emotionally prepare for a foreseen stressful event?
- Field experiment of the PT and the Booth: What are the weaknesses, and educational opportunities of using the PT and *the Booth* in a secondary school oral communication course.

Chapter VII starts by addressing one of the gaps exposed by the expert study (Chapter V). Experts interviewed in Chapter V expressed some concerns about a tool that is only able to provide corrective feedback, since according to them ultimately there is not a right way to do a presentation. However, they indicated that a tool such as the PT has a great potential in helping learners in public speaking to become more aware of their performance. The study in Chapter VII explores the use of a self-reflection module developed with the purpose to help learners to become more aware of their performance. It reports a user evaluation where participants practiced an elevator pitch two times using the version of the PT that included the newly implemented self-reflection module.

Results from this study revealed that in general participants show their appreciation for the self-reflection module. They reported that the self-reflection module was relatively easy to understand, and helped them to become aware of their own performance. Based on the acquired self-awareness from the first practiced pitch, participants made a conscious effort to improve certain behaviors during the second one. Observations made during the study showed how participants were able to maintain this conscious effort only for the first few seconds of their pitch; therefore the study shows no significant effects from the self-reflection module in the participants' performance.

This suggests that more practice time is required in order to obtain significant evidence on the effects of the self-reflection module in the participants' performance. The most interesting result from this study is that one third of the participants, without being asked, stated the importance of rewriting the script of their pitch based on the information presented by the self-reflection module.

The exploration on sensor-based applications designed to support the development of public speaking skills continued by investigating how to help learners with the affective aspect of public speaking. People usually suffer from some type of anxiety when speaking to the public (Hofmann, Gerlach, Wender & Roth, 1997). This anxiety is responsible to undermine executive functions such as reasoning, task flexibility, attention control and performance (Derakshan, & Eysenck, 2009), therefore it is important to support learners in the preparation of a supportive mindset (Raman et al., 2013; Cuddy, 2016b). Chapter VIII researches how sensor applications can be used to support learners in the preparation of a supportive mindset. It investigates the effects that the use of *the Booth* has in the emotional state of users. *The Booth* is a sensor-based application that guides the user through a set of psychological exercises designed to help people to reduce feelings of stress and anxiety, while increasing feelings of confidence and personal power. Chapter VIII presents a two-step study. In the first step of the study participants used *the Booth* in an ordinary daily circumstance and in the second step participants used it before giving a presentation (a mildly stressful circumstance). Results of the two-step study show that in both circumstances participants, after using *the Booth,* reported to have significantly more positive emotions such as happiness, joy, enthusiasm, etc. and significantly less negative emotions such as anger, stress, anxiety, etc.

After gaining evidence that sensor-based applications can support learners in developing their nonverbal communication skills for public speaking and support them in getting a supportive mindset before speaking to the public it is important to study how sensor-based applications can be introduced and can enhance current educational practices.

Chapter IX describes a field study conducted in a secondary school where first grade students following a five-week course on oral communication used the PT and *the Booth*. The aim this study was to identify the weaknesses and educational opportunities of these tools. The study started in the second week of the course, was conducted during the time of the lectures, and consisted of two sessions. For the first session students practiced twice a short presentation using the PT. Two weeks later, during the second session some of the students practiced their short presentation one time using the PT, and then they gave the presentation to two of their peers. The remaining students used *the Booth* to prepare for a presentation, and then they gave their presentation to two of their peer students.

Results from the study show that students identified the PT as a novel application. They reported to feel motivated to use the PT in the future, and considered it as a useful learning tool. Results from this study suggest that users without experience in giving presentations can benefit only to a certain extent from the use of the PT. Results pointed out that the current version of the PT, as a stand alone application for novice learners is not comprehensive enough. Before a practice session with the PT, novice learners need to be reminded about the nonverbal communication aspects to be trained. The self-reflection module of the PT helps novice learners to identify unwanted behavior, but it does not provide them with the information required to help them to improve. Giving a presentation to a pair of peers has shown to be stressful for the participants in the study. Participants who used *the Booth* to mentally prepare for their presentation reported to feel emotionally better while giving it and also felt more satisfied about their performance.

Unreported Findings

Some important findings appear throughout the research conducted for this dissertation that are important for the subject of sensor-based learning support and were not reported in any of the specific studies. When creating a sensor-based application designed to give feedback to learners it is important to find an answer to the following questions:

- “What do we want to infer from the learner’s performance?” The type of sensors used in an application does not necessarily constrict the inferences regarding the learner’s performance. Different types of sensors, measuring different types of physical units can be used to infer the same particular aspects of the learner’s performance.
- “How to translate the inferences of the learner’s performance into a feedback model that is effective for learning? ” With a human tutor feedback appears in the form of a natural dialogue, where the tutor intuitively knows when to give feedback and the learner can ask for clarification. There is no opportunity of dialogue with the sensor-based feedback prototypes presented here, therefore it is important to define and study what type of feedback, when, and how to present it to the learner.

Human feedback has an informative aspect and an emotional aspect; it can be very inspiring for the learner, but also very emotionally draining for both the tutor and the learner. In contrast sensor-based feedback appears to have mainly a functional perspective for learners according observations made during the research conducted for this dissertation. Learners will use it as long as they judge it useful without any substantial affective effect.

Learners show a natural trust regarding the accuracy and objectivity of sensor-based feedback even when it is explained to them that the application just follows some simple rules and is not one hundred percent accurate. Therefore, when giving corrective feedback it is recommendable to sacrifice some accuracy in detecting all mistakes in order to avoid false positives as much as possible.

It is also important to remind learners that sensor-based assessment and thus its feedback at the moment is limited. It is not able to interpret the meaning behind their performance. Hence, sensor-based applications for learning should help learners to reflect about their performance letting them know that they are the final judges of their own actions.

Limitations

The research conducted for this dissertation presents three types of limitations: Limitations due to the scope of the research project, limitations regarding the results of the studies, and limitations of sensor-technologies for learning.

The scope of the project restricted the amount of learning topics selected to conduct research on sensor-based learning support. As shown in the literature review sensor-based learning support can be applied to a vast amount of learning topics. However, due to the scope of the project the research presented in this dissertation mostly focuses on researching the use of sensor-based applications to support the development of non-verbal public speaking skills. Interpreting for any given topic the natural language spoken during a presentation and provide feedback about it, is an extremely complex task left out of the project. Therefore, the conducted research was constrained to study the support of a limited set of nonverbal communication skills for public speaking.

The results obtained in the different studies conducted for this dissertation have also some limitations. When looking at the learning effects of using the PT, results from the studies in Chapter IV, VI, VII and IX provide evidence that on the short-term practicing with the PT helps learners to significantly improve their performance. However, the studies did not, or only very limitedly, focused on medium and long-term learning effects. The study in Chapter IX aimed to explore the medium-term usage of the PT, identifying the PT's medium-term learning effects and the learners' motivation to practice with it. Nonetheless, two main factors did not allow the exploration of these medium-term effects. First, the availability of participants unexpectedly changed during the course of the study. Second, the difference between the effects of the PT in learners with some experience in public speaking and the effects of the PT in complete novice learners was unexpected. Hence, there is no conclusive evidence of the medium-term effects of using the PT. Also the study described in Chapter VI had some methodological issues. Due to the number of available participants and time constraints, it was not feasible to conduct an experiment with a treatment group practicing with the support of the PT and a control group practicing without support. Therefore, it is not possible to determine to what extent the observed improvements in this study are the result of practicing with the PT, or just the result practicing.

Improving performance according to the measurements of the PT is an indication of learning, but not necessarily an indication of becoming better presenters. One way to address this gap is by validating the model of assessment and feedback used by the PT. One of the purposes of the study in Chapter V is to identify a valid set of nonverbal communication behaviors that affect the quality of a presentation, and later use it to create a valid model of assessment. This set of nonverbal communication behaviors is by no means exhaustive; only ten experts from similar cultural background were interviewed to obtain this set. Additionally, it is important to acknowledge that some of the identified behaviors might have a different meaning in different cultural contexts.

A sensor-based application designed to support the development of public speaking skills that only corrects learners presents some limitations, since there is not a right way to do a presentation as the experts interviewed in Chapter V stated. This limitation was tackled with the creation of a self-reflection module for the PT. Chapter VII presents a study where participants practiced with the PT and tested this self-reflection module. Results from this study show that participants appreciated the module and asserted that it helped them to become more aware of their performance. However, results from the study show no evidence regarding the influence of the self-reflection module in the participants' measured performance.

Having mastered some basic nonverbal communication skills while practicing with the PT is not of much help if one gets nervous in front of an audience and therefore is not able to give a good presentation. *The Booth* aims to address this issue by supporting learners with the acquisition of a mindset that helps them to perform well in foreseen stressful situations. Chapter XIII and Chapter IX present studies describing the use of *the Booth*. Results from these studies revealed that after using the Booth participants reported to have more positive emotions and less negative ones. It is important to state that there might be a discrepancy between the reported emotions and the actual emotional state of participants after using *the Booth*. Moreover, there is no evidence indicating that the mindset acquired by using *the Booth* helps learners to perform well.

The research conducted for this dissertation identified some limitations regarding the use of sensor-technologies for learning. Sensors itself only capture specific aspects of reality and to a limited level of accuracy. Sensors might become more accurate in the future, but still they will present some limitations. As stated in the main findings of this dissertation when thinking about sensor-based learning support it is important to explore what can be inferred out of the sensor data. Models need to be used for these inferences and models will always present some limitations. In the specific case of public speaking, the content of a speech has an enormous importance, and is tightly coupled with the nonverbal communication. Currently Natural Language Processing technologies are not able to analyze if the content spoken by the learner while practicing a presentation makes sense. Hence, the learning support that a tool such as the PT can give is restricted.

While accessibility of sensors is quickly increasing, it is still fairly limited. Only a very few percentage of learners have access to depth cameras such as the Microsoft Kinect V2 and can benefit from sensor applications such as the PT and *the Booth*, which during the studies conducted for this dissertation have started to show their potential as tools for self-study.

Implications for future research

A natural path to extend the research presented in this dissertation is by starting a new iteration of the design-based research approach with the focus to address the limitations and weaknesses concerning the use of the PT and *the Booth* in the field pointed out in Chapter IX. The study in this chapter pointed out the relevance creating a study course for the PT, with lessons that include small lectures explaining basic principles of public speaking that can later be practiced using the help of the PT. By setting up a study with participants following the course, it would become possible to study the medium and long-term effects of using the PT. The PT could be enhanced with a learning analytics module able of storing the measured performance of the learners and displaying their progression through the course.

The current assessment and feedback model of the PT could be expanded based on the behaviors identified in the expert study (Chapter V). At its current state, the PT provides immediate feedback only about ineffective communication practices (mistakes), instructing learners to correct their behavior. Besides the addition of more mistakes, the expanded assessment model of the PT should also be able to identify a set of effective communication practices. Thus, for future research it is worth studying how to differentiate between the corrective feedback for the identified mistakes, and the feedback for the identified effective communication practices.

The novelty of the PT and *the Booth* played a big role in the motivation and engagement shown by participants in the studies conducted for this dissertation. For future research it is important to study how to maintain a high level of motivation and engagement for using these tools once their novelty effect fades away. In the case of the PT this could be achieved through the design of interesting lessons for the already discussed study course. In the case of *the Booth* this could be achieved by the addition of new lectures, and randomly rotating these lectures so that the time of preparing with *the Booth* keeps on being short while remaining fresh for the learners.

The presented research revealed some findings that extend beyond the realm of using sensors to support the development of public speaking skills, and contribute to the future research of and usage of sensor-based learning support in general. *The Booth* showed to help learners to increase some positive emotions and decrease negative ones when used before giving a presentation, hence helping learners to mentally prepare for speaking in public. Similar results are expected when using *the Booth* before other types of mildly stressful events such as a job interview, important negotiation, doing a test, competing in a sport event, or any type of public performance.

The immediate feedback mechanism of the PT receives a constant stream of data from different sensors. Instead of feeding it forward to the learner, the feedback mechanism analyses the data and selects at maximum one "simple" feedback instruction to be communicated to the learner. This sensor-based feedback mechanism has revealed to be effective in supporting the development of public speaking skills, even when the PT is not able to interpret the content spoken by the learners nor the purpose behind their nonverbal communication. It suggests that when a framework of grounded heuristics is available or can be derived, it suffices the design of a feedback mechanism. The meaning behind the actions performed by learners do not need to be understood by sensor-based applications in order to support learners through the discussed sensor-based feedback mechanism. The addition of a self-reflection mechanism asking questions to learners regarding their tracked performances helps them to identify if they were acting purposely and lets them decide whether their performance was correct or incorrect. Hence, it makes the sensor-based feedback more comprehensive and helps to address the current limitation of sensor applications not being able to understand the meaning behind the learners' performance. This immediate feedback mechanism and self-reflection mechanism could be generalized presenting learning support beyond the development of public speaking skills. The research presented in this dissertation suggests that these immediate and self-reflection feedback mechanisms can support the development of different type of skills whose techniques require practice and feedback in order to be mastered. Examples of these skills can be: sport activities where mastering a technique is important, performing arts, negotiation skills, talking to patients and clients, deescalating conflicts, and any type of communication skill where nonverbal communication is relevant.

In summary, the presented research has shown that technically it is possible to use sensors to track the learner's actions, and use the tracked sensor data to make inferences about the learner's performance. Educationally it has been shown that it is possible to assess and provide feedback about the inferred performance in ways that have a positive effect on learning. It has also shown that sensors can support learners with the acquisition of a positive emotional state. Overall, this research presents strong arguments indicating that sensors can become a driving factor in the evolution of interactive learning technologies.

Into the future

Aristotle said that all education is but a preparation for some worthy activity (Davidson, 1892). My perception after having studied and worked in four different universities world wide, listened to talks by ministers in education, attended to conferences and graduate schools in technology enhanced learning, and read multiple scientific articles in the topic, is that the current approach to education aligns with the proposition of Aristotle. At a practical level it is difficult to deny that at current times the main objective of education is to prepare students to meet the workforce needs, even when at some idealistic level one can still find arguments stating that education should contribute to the search for truth, improvement of the human condition, etc.

A result of this pragmatic view to education is that it puts a spotlight on the activities that the student will be able to perform after completing an educational program, rather than the student. This focus on the activities rather than on the individuals spreads to other aspects of society such as the workforce where the job done becomes more important than the individual doing the job.

For ages this pragmatic way of thinking helped to identify the value in other human fellows. Throughout history our value as job doers has become evident. Our innate ability to learn and use technologies has helped us to excel at our jobs, leaving our competition far behind, and highlighting the immeasurable value of being human. For how much longer will this be the case?

As humans we are pretty good at recognizing our mechanical limitations, and are able to acknowledge that in terms of mechanical capacities and features technology has already exceeded our abilities long time ago. However, we humans are not that good at recognizing our mental limitations (Ariely, 2008) and have some difficulties acknowledging that one day technology might catch up with us. Technology is evolving at incredible rates. We are failing to recognize that day-by-day technology is becoming more efficient, cheaper and better than us at performing tasks that we consider complex. Technology has already become better than the best of us at intellectual tasks such as playing Go (Silver et al. 2016), answering questions in natural language (Markoff, 2011), playing chess (Hsu, 1999), data science competitions (Kanter & Veeramachaneni, 2015). Even for mundane tasks such as mowing the lawn it is possible to realize that technology has become better than us.

What is the value of education and learning, if technology becomes better at and cheaper at doing our jobs?

When I started the research on sensor-based learning support I justified it by stating that sensor-applications could help with formative assessment and feedback, since giving this kind of interventions to all learners is neither feasible nor affordable. This seems to be a noble justification but deep inside it just felt wrong, because I believed that at the end I was just investigating how to replace human teachers. Fortunately, this view changed. During the expert study, experts stated that their courses could be improved by letting students do their homework with a tool such as the PT. Throughout my studies, I also started to see differences between human feedback and sensor-based feedback. I discovered that human feedback has always for good and for bad an emotional impact on learners, while sensor-based feedback has none. This made me realize that both forms of feedback could complement each other enhancing the experience of the learner. Suddenly I felt good about my research.

Socrates identifies different types of knowledge, important and trivial. He acknowledges the relevance of having the knowledge needed to practice a craft, but for him the most important knowledge is "how best to live" (Brickhouse & Smith, 2000). I agree with this statement, and suggest that helping students to acquire this important knowledge should be the primary goal in education. Naturally, acquiring this kind of knowledge is difficult, even Socrates states that there is not an easy answer to "how to best live". However, I believe that enhancing the human experience with the use of technology can help to reach this goal.

Humans are much more than working gears of the economy. We are also vulnerable and selfish beings full of doubts, insecurities and fears. Beings that when confronted with a glimpse of important knowledge, are able to use all their love to overcome all types of limitations and create performances, art, literature, music, philosophy, science, technology, etc. that pushes the boundaries of the human spirit rising it to unprecedented levels. Our civilization and achievements outshine in complexity everything in the known universe. We open our eyes 200 000 years ago, let's look at our journey and realize how far we have gone, embrace who we are, and think for a moment where we would like to take our next step into the future.

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Appendices

Appendix A. Identified sensors together with their measured property and identified functions

Sensor	Measured Property	Helps with	Installation
Accelerometer	Acceleration	Activity sensing, Context sensing, Environment sensing, Physiological state sensing	Environmental, Wearable
Air pollutants sensors	Amount of toxic particles in the atmosphere	Context sensing, Environment sensing	Environmental, Wearable
Barometer	Pressure	Activity sensing, Context sensing, Physiological state sensing	Environmental, Wearable
Blood glucose meter	Glucose on the blood	Physiological state sensing	Wearable
Bluetooth	Radio signals	Activity sensing, Context sensing	Wearable
Camera	Visual light	Activity sensing, Context sensing, Environment sensing, Physiological state sensing	Environmental, Wearable
Compass	Earth magnetic field	Activity sensing	Wearable
Electro cardiogram (ECG or EKG)	Heartbeat	Activity sensing	Wearable
Electrodermal activity meter (EDA)	Skin conductance	Physiological state sensing	Wearable
Electroencephalogram (EEG)	Electrical activity along the scalp	Activity sensing, Context sensing Physiological state sensing	Wearable
Electromyography sensor	Electrical activity produced by skeletal muscles	Activity sensing	Wearable
Force gauge	Force	Activity sensing	Wearable
Galvanic skin response sensor	Skin conductance	Context sensing, Physiological state,	Wearable
Global positioning system (GPS)	Earth coordinates	Activity sensing, Context sensing, Environment sensing	Environmental, Wearable
Global system for mobile (GSM)	Radio signals	Context sensing	Environmental, Wearable
Gyroscope	Measures orientation	Activity sensing, Context sensing, Physiological state sensing	Wearable
Humistor	Detects humidity	Activity sensing, Physiological state sensing	Wearable
Infra red camera	Infra red frequency of light	Activity sensing, Context sensing	Environmental, Wearable
Microphone	Sound waves	Activity sensing, Context sensing, Environment sensing	Environmental, Wearable
Near Field Communication receiver	Radio frequency	Context sensing	Environmental, Wearable
Radio frequency identification receiver	Radio frequency	Context sensing	Wearable,
Sonar	Detect objects through sound waves	Activity sensing	Wearable
Software Sensors	Detect user's actions	Activity sensing Context sensing	Environmental, Wearable
WiFi	Radio frequency	Context sensing	Environmental, Wearable

Appendix B. List of the analyzed prototypes during the literature review

Prototype	Learning Domain	Formative Assessment Contribution	Sensors Used	Description
Ailisto *et al.*, (2006)	Cognitive	-	Cameras RFID readers	It reads tags placed in objects in order to present more information about them.
Anderson & Reiser (1985)	Cognitive	Feedback	Software Sensors	A tutoring system that helps students when having trouble solving some problems for the lisp programing language.
Amaratunga *et al.*, (2002)	Cognitive	-	Accelerometers	It monitors the movement of a flagpole and streams this data through the network creating a virtual lab.
Arroyo *et al.*, (2009)	Cognitive	Attitudes towards teaching	Camera, Galvanic skin conductance, pressure mouse, accelerometers.	It is a prototype that detects the emotional state of students while interacting with an intelligent tutoring system.
Baca & Kornfeind (2006) - Biathlon	Cognitive	Knowledge of subject matter Knowledge of criteria and standards Feedback	Camera	It analyzes the movement of the rifle.
Baca & Kornfeind (2006) - Rowing	Cognitive	Knowledge of subject matter Knowledge of criteria and standards Feedback	Force transducer	It is analyzes the rowing technique.
Baca, & Kornfeind (2006) - Table tennis	Cognitive	Knowledge of subject matter Knowledge of criteria and standards Feedback	Accelerometers	It analyzes the position of the table tennis shots.
Börner *et al.*, (2014)	Cognitive	-	Camera	It is a ambient display that adapts its behavior to capture the attention of learners.
Broll *et al.*, (2011)	Cognitive	-	NFC	It is a game where players need to touch parts of a screen with NFC readers
Chapel (2008)	Cognitive	-	GPS NFC WiFi	It provides a communication system for students in a university.
Chavira *et al.*, (2007)	Cognitive	-	RFID NFC	It gives contextual information to the participants of a conference.
Chen & Huang, (2012)	Cognitive	Skills in setting Evaluative skills Feedback	RFID	It gives a tour through a museum.
Chu *et al.*, (2010)	Cognitive	-	RFID	It gives a tour through a botanic garden.

Prototype	Learning Domain	Formative Assessment Contribution	Sensors Used	Description
Dung & Florea (2012)	Cognitive	Feedback	Software sensors	It detects the learning style of students and presents them later with learning objects fitting their style.
Edge *et al.*, (2011)	Cognitive	-	GPS	It helps to learn a second language by presenting users with contextual phrases.
Ghasemzadeh *et al.*, (2009)	Cognitive	Knowledge of subject matter Knowledge of criteria and standards	Accelerometers	It analyzes golf swings.
GlobiLab for middle & high schools	Cognitive	-	-	Commercial software to visualize and analyze sensor data.
Greene (2010)	Cognitive	Knowledge of subject matter Knowledge of criteria and standards	Gyroscopes	It analyzes the user's gait.
Hester *et al.*, (2006)	Cognitive	Knowledge of criteria and standards Skills in setting	Accelerometers	It measures the movements of people who have suffered a heart stroke.
Hicks *et al.*, (2010)	Cognitive	Self-Assessment Feedback	Accelerometer GPS	It captures the health and behavior of the user, with the sensors of a mobile device
Hsu & Ho (2012)	Cognitive	Knowledge of subject matter Knowledge of criteria and standards Evaluative skills Feedback	NFC	It chooses the learning path of the learner according to its tracked competences
James *et al.*, (2004) swimming	Cognitive	Knowledge of subject matter Knowledge of criteria and standards	Accelerometers	It analyzes the movements of the user while swimming.
James *et al.*, (2004) rowing	Cognitive	Knowledge of subject matter Knowledge of criteria and standards	Accelerometers GPS Heart rate monitors	It analyzes the movements and applied forces of the user while rowing.
Jraidi, & Frasson, (2012)	Cognitive	-	EEG	It detects the uncertainty of students while performing exercises in an intelligent tutoring system.
Kaasinen *et al.*, (2009)	Cognitive	-	NFC	It reads tags placed in objects in order to present more information
Kanjo (2009) MobAsthma	Cognitive	-	Air pollutants sensors GPS Software sensors	It measures the air pollution and compares it asthma cases.
Kanjo (2009) [42] NoiseSpy	Cognitive	-	GPS Microphones	It measures the noise pollution.

Prototype	Learning Domain	Formative Assessment Contribution	Sensors Used	Description
Kanjo (2009) PollutionSpy	Cognitive	-	Air pollutants sensors GPS	It measures the air pollution.
Karime *et al.*, (2011)	Cognitive	-	RFID	It is a magic wand that recognizes objects and displays information about them on an ambient screen.
Kozaki *et al.*, (2010)	Cognitive	Knowledge of subject matter Knowledge of criteria and standards	Accelerometers ECG	It tracks the motion of the user in order to infer its activity
Kubicki *et al.*, (2011)	Cognitive	-	RFID	It is an interactive tabletop able to identify tangible objects.
Kuflik *et al.*, (2011)	Cognitive	-	RFID	It is a mobile guide for museums.
Lee & Carlisle (2011)	Cognitive	Knowledge of subject matter Knowledge of criteria and standards	Accelerometers GPS	It detects falls using the accelerometer of mobile devices.
Linden *et al.*, (1996)	Cognitive	Feedback	EEG	It trains children with ADD to pay attention.
Littlewort *et al.*, (2011)	Cognitive	Attitudes towards teaching	Camera	This prototype tracks the facial expressions of kids while solving problems using a tutoring system.
Logger Pro	Cognitive	-		Commercial Software to visualize sensor data.
Lu *et al.*, (2009)	Cognitive	-	Microphone	It uses the microphone of the mobile device of the user to identify its context and present information about it.
Mandula *et al.*, (2011)	Cognitive	Skills in setting Evaluative skills	RFID	It identifies indoor locations and objects in order to give contextual information to the user.
Maisonneuve *et al.*, (2009)	Cognitive	-	Microphone GPS	It measures the noise pollution.
Muñoz-Organero *et al.*, (2010)	Cognitive	-	RFID	It uses sensors to identify objects and give information about them.
Muñoz-Organero *et al.*, (2010) Network Lab	Cognitive	Skills in setting	RFID	It identifies objects on a network lab and gives information about them to the users.
Nijholt *et al.*, (2007)	Cognitive	-	Cameras	It captures and displays the non-verbal input of the user.
Pentland (2004) Memory Glasses	Cognitive	Feedback	Bluetooth GPS Software Sensors	It triggers reminders to the user according to its context
Pérez-Sanagustín *et al.*, (2012)	Cognitive	-	NFC RFID	It provides contextual information to students inside of the university campus.
Rahman, & El Saddik (2012)	Cognitive	-	Accelerometers Infrared cameras	It gets information about objects by pointing at them.

Prototype	Learning Domain	Formative Assessment Contribution	Sensors Used	Description
Ramírez-González *et al.*, (2012)	Cognitive	Skills in setting	NFC	It allows teachers to create information about objects so that students can access this information later.
Serbedzija & Fairclough (2012)	Cognitive	-	Heart-rate monitor Electromyography GPS Speedometer	It adapts the cockpit of a car according to the user's state and driving rules.
SPARKvue	Cognitive	-		Commercial Software to visualize sensor data.
Spelmezan, Schanowski & Borchers (2009)	Cognitive	-	Bend sensors Force sensors Inertial sensors Software Compass	It tracks important moments during snowboarding.
Strachan (2005)	Cognitive	Feedback	GPS	It helps users to navigate through sounds.
Szafir & Mutlu (2013)	Cognitive	Knowledge of criteria and standards Skills in setting Feedback	EEG	It tracks the attention level of students during a virtual lecture, and recommends which subjects to review after it.
Whitehill *et al.*, (2008)	Cognitive	Knowledge of criteria and standards	Camera	The prototype determines the speed at which lesson material should be presented in a tutoring system according to the facial expressions of the learner.
Garrido (2011)	Cognitive - Affective	Skills in setting Evaluative skills	NFC RFID	It is a game where objects can be found by using sensors.
Heggen (2012)	Cognitive - Affective	Skills in setting	Accelerometer Camera Microphone GPS	It uses the sensors on a mobile device to gather scientific data.
Carroll *et al.*, (2013)	Affective	Self-Assessment Feedback	Accelerometer ECG Electro dermal activity	It monitors the emotional state of the user and keeps track of its eating habits.
Consolvo *et al.*, (2008)	Affective	Self-Assessment Feedback	Accelerometer Barometer Camera Compas Humistor Microphone Thermometer microphone	It monitors and keeps track of the physical activity of the user.

Prototype	Learning Domain	Formative Assessment Contribution	Sensors Used	Description
Froehlich *et al.*, (2009)	Affective	Self-Assessment Feedback	Accelerometer Barometer Infrared camera GSM	It monitors and keeps track of the means of travel by the user.
Hsieh *et al.*, (2008) [72]	Affective	Self-Assessment Feedback	Software sensors	It monitors and keeps track of the user's activities.
Pentland (2004) DiabeNet	Affective	Self-Assessment Feedback	Blood glucose meter Software sensors	It monitors the glucose condition of the user.
Verpoorten *et al.*, (2009)	Affective	Feedback	Software sensors	It adapts a virtual learning environment according to the learner's actions and interests.
Aukee *et al.*, (2004)	Psychomotor	Feedback	Biofeedback (Barometer)	It gives feedback about the pelvic floor activity, and it is used to improve incontinence.
Bevilacqua *et al.*, (2007)	Psychomotor	Knowledge of criteria and standards Feedback	Accelerometers Gyroscopes	It maps gestures taught on a music lesson to sounds.
Brunelli, *et al.*, (2006)	Psychomotor	Feedback	Accelerometers Inertial sensors	It corrects the posture of people going through a rehabilitation process.
Burish, & Jenkins (1992)	Psychomotor	Feedback	Electromyograph Thermometer	It teaches patients going through Chemotherapy how to relax.
Cockburn *et al.*, (2008)	Psychomotor	Feedback	Cameras	It is a game that trains children with autism to perform some facial gestures.
Hoque *et al.*, (2013)	Psychomotor	Feedback	Cameras Microphones	It is a prototype that helps learners to develop social skills for job interviews
Kranz *et al.*, (2006)	Psychomotor	Feedback	Accelerometers Gyroscopes RFID	It corrects the movements of patients going through physiotherapy.
Kwon & Gross (2005)	Psychomotor	Feedback	Accelerometers Cameras	It is a motion training system for martial arts.
Lehrer *et al.*, (2000)	Psychomotor	Feedback	ECG	It trains users to breath according to the heartbeat.
Li *et al.*, (2012)	Psychomotor	Feedback	Camera	It is a game based psychomotor skill training for kids with autism.

Prototype	Learning Domain	Formative Assessment Contribution	Sensors Used	Description
Paradiso *et al.*, (2004)	Psychomotor	Feedback	Accelerometers Barometers Gyroscopes Sonar	It produces different sounds according to the gait of the users.
Spelmezan & Borchers (2008)	Psychomotor	Knowledge of subject matter Knowledge of criteria and standards Feedback	Bend sensors Force sensors Inertial sensors Software Compass	It helps to train the snowboarding technique.
Spelmezan *et al.*, (2009)	Psyhomotor	Feedback	Bend sensors Force sensors Inertial sensors Software Compass	It helps to train the snowboarding technique using haptic feedback.
Takahata *et al.*, (2004)	Psychomotor	Feedback	Accelerometers Cameras	It helps to train karate movements.
Vales-Alonso *et al.*, (2010)	Psychomotor	Feedback	Barometer Heart-rate monitor Humistor Thermometer	It helps cross country runners with its training.
Van der Linden *et al.*, (2011)	Psychomotor	Feedback	Inertial motion capture sensors	It is a prototype that helps learners to practice certain movements while playing violin.
Verhoeff *et al.*, (2009)	Psychomotor	Feedback	Accelerometers Gyroscopes	It gives feedback according to the user's gait.
Chang *et al.*, (2009)	-	-	Humistor Light sensors NFC RFID Thermometers	It is a house that adapts certain aspects automatically according to the user's preferences
Hsu (2010)	-	-	RFID	It is a house that adapts the music being played automatically according to the user's preferences.
Krause *et al.*, (2006)	-	-	Accelerometer Galvanic skin response Thermometer	It is a mobile phone that changes its behavior according to the user state and surroundings.

Appendix C. List of Nonverbal communication practices for giving presentations

Ineffective Practices	# Of Experts mentioning the behavior	Good Practices	# Of Experts mentioning the behavior
I. Posture			
• Giving the back to the audience	7	• Feet between shoulder and waist width firmly on the ground	8
• Dancing	6	• Shoulders back and relaxed	8
• Hands in pockets	5	• Chin up	7
• Hands behind the back	5	• Facing the audience	7
• Hands touching hair	5	• Open posture	7
• Hands touching face	4	• Hands loose next to your body with palms facing the audience	2
• Crossing legs	4	• Neck back	2
• Hands grabbing and playing with something	4	• Hands together just above the belt, without interlacing	2
• Hiding yourself	4	• Posture where you feel at ease with yourself	2
• Fiddling with hands	4	• Point toes to audience	1
• Neck forward	3	• Arms relax, one hand grabbing the thumb of the opposite hand	1
• Crossed arms	3		
• Hunch	3		
• Closed posture	3		
• Standing with the bodyweight on one leg	2		
• One leg in front of the other	1		
II. Gesture			
• No gestures	7	• Gestures bigger than usual	5
• Waving both arms above the shoulders	4	• Delivered gestures	5
• Holding things	4	• Gestures for enumeration and sequences	5
• Touching face, hair, etc. without a specific purpose	4	• Gestures for emphasis	5
• Playing with notes	4	• Gestures to explain and paint the picture	5
• Holding hands without a specific purpose	3	• Make a gesture and return to your posture	5
• Crossing arms without a specific purpose	2	• Vocalize gestures	4
• Waving arms below the hips	1	• Slower gestures	4
III. Facial Expression			
• Blank face	9	• Smile	8
• Grinning like an idiot all the time	1	• Congruent with the content	7

Ineffective Practices	# Of Experts mentioning the behavior	Good Practices	# Of Experts mentioning the behavior
• Lack of enthusiasm	1	• Show the emotion you want to transmit	4
IV. Eye Contact			
• No eye contact	8	• Screen the audience and give as much eye contact as possible	10
• Fixed eye contact	8		
• Reading	5		
• Give back to the audience	4		
• Facing screen	4		
V. Use of Stage			
• Stand behind the computer screen, desk or lectern	6	• Move with purpose	5
• Move constantly from one side to the other	4	• Stand in a place where you can be seen	4
VI. Voice			
• Talking out-loud to yourself	8	• Speak to the audience	7
• Be aware only of the content	8	• Breath from belly	4
• Filler sounds such as: hmm, ahm, etc.	5	• Stress important words	4
• Monotone voice	3	• Match the emotion with message you want to convey	4
• Speaking too fast	2	• A bit louder than usual	2
• Not loud enough	2	• A bit slower than usual	2
• Dropping volume end of the sentence	2	• Changes on voice volume	2
• High pitch	1	• Voice according to phases of the presentation	2
• Mumble	1	• Lower pitch Men	1
		• Higher pitch Women	1
		• Signaling new topic with higher pitch on first word	1
		• Make clear the end of each sentence	1
VII. Pauses			
• Not pausing	10	• Big pause after telling something important	6
• Hurrying up	7	• Big pause after asking a question	6
• No difference between small and big pause	4	• Big pause before starting next topic	5
		• Small pause after every sentence	2
		• Big pause letting people read the slide, before you talk about it	2
		• Every 3 to 5 sentences a big pause	1
		• Good timing	1

Ineffective Practices	# Of Experts mentioning the behavior	Good Practices	# Of Experts mentioning the behavior
		• Longer pauses than usual	1
		• Chunking sentences and use small pauses between the chunks	1
VIII. Walking to the stage			
• Hurry to the stage	3	• Walk slow and confident while giving eye contact to the audience	3
• Shuffling	2		
• Negative self talk	1		
• Ignore that the Presentation already started	1		
IX. Settle in Time			
		• Take your time	10
		• Get grounded	5
		• Deep breaths	4
		• Claim territory	1
		• Stand closer to the audience	1
X. Introduction			
• Starting with high pitch	1	• A lot of eye contact (more than usual)	6
		• Lots of Pauses	4
		• Lots of voice variation (volume, pitch)	4
		• Speak loud	4
		• Theatrical	3
		• Open arms	3
		• Prepared start	2
		• Come close to the audience	2
		• Low pace	2
		• Enthusiasm (smile)	1
XI. Middle			
• Monotonous speech	7	• Change dynamics	8
• No stress on important words	2	• Less energy as in the beginning	3
• Not using the stage	2	• Look away when trying to remember something or after a rhetorical question, and then look back again	1
XII. Conclusion			
• Not having a full stop	6	• Big pause before giving it	8
• Not signify that is coming	5	• Slow and clear	6
• Ending with: "And that's it"	4	• Make yourself big (Open posture, arms extended)	3
• Losing energy	1	• Come closer to the audience	1
		• Keep breathing	1
XIII. Questions and Answers			

Ineffective Practices	# Of Experts mentioning the behavior	Good Practices	# Of Experts mentioning the behavior
• Focus only on the person asking the question	3	• Acknowledge question to person who asked the question	4
• Pointing with a finger to the person asking	1	• Give answer to everybody in the audience	4
• Bad timing, not giving time for questions	1		

Summary

This dissertation reports on the research conducted with the purpose to investigate the use of sensors to support the learning process. The research starts by studying the state-of-the-art on the use of sensors to support learning. Then it gets into the context of the Metalogue project and explores the use of sensors to support the development of public speaking skills following a design-based research approach that comprised of three iterations.

A systematic literature review (Chapter 2) was conducted in order to study the state-of-the-art concerning the use of sensors to support learning. This literature study analyzes 82 different sensor-based prototypes based on their potential contribution to the cognitive, affective and psychomotor domain of learning. The study continues by exploring how the selected sensor-based prototypes can support the implementation of formative assessment, and finishes with a comprehensive analysis on the feedback mechanisms of the prototypes.

Results from this study show that sensor applications can provide support to the three commonly identified learning domains and can be used for a vast range of learning topics including science, sports and arts among others. Sensor applications may support the implementation of formative assessment by supporting key aspects of it, such as knowledge of the subject matter, knowledge of criteria and standards, attitudes towards teaching, skills in setting evaluative skills, self-assessment, and feedback. The analysis of the prototypes also revealed the early state of maturity of sensor-based learning support since the learning effects of the prototypes were hardly ever studied, the feedback mechanisms of the prototypes were hardly ever justified, the immediate feedback mechanism of the prototypes was limited to the emission of one signal, and most of the sensor-based prototypes did not implement a comprehensive educational design.

The first iteration of the design-based research approach starts with a formative study (Chapter III) on the Presentation Trainer (PT), which is a tool designed to support the development of basic nonverbal communication skills for public speaking. It captures, analyzes and provides in real time feedback regarding certain aspects of the user's nonverbal communication such as posture, use of gestures, use of pauses, and voice volume. This study reports on the user studies conducted for the first two versions of the PT.

The first version of the PT provides feedback to users with a dashboard consisting of feedback items that work as semaphores changing from green to red whenever a

mistake of the user is identified. Results from the user tests of this first version of the PT show great enthusiasm from participants towards practicing with it for future presentations. However, participants stated the difficulty of paying attention to all the feedback items while practicing at the same time. Moreover it was observed that participants were not able to adapt their behavior based on the feedback provided by the PT.

The second version of the PT was improved based on the findings of the first user study. This second version of the PT contains two user modes: an exercise mode and a freestyle mode. The exercise mode guides users through a series of different type of exercises designed to help with the automation of certain behaviors (e.g. talking a bit and returning to a reset posture, talking louder, talking softer, etc.). The freestyle mode works similar as the first version of the PT, however the visual aspects of the dashboard interface were improved. An enhanced mirror image of the learner was added, highlighting a posture mistake through the skeleton representation of the learner. Instead of balls working as semaphores this new dashboard interface highlights icons displaying two-word instructions on how to correct the mistakes.

The user tests of this second version of the PT pointed out three main findings:

- An exercise mode can help with the automation of certain behaviors.
- Before using the PT an explanation on how to correctly respond to its feedback is required.
- A dashboard interface giving feedback in multiple aspects at the same time is not optimal for learning.

Based on these findings a new version of the PT was developed. This new version analyzes the behavior of the user and based on this analysis, it provides the user with at maximum of one feedback instruction at a given time. If the user repeats a mistake several times or does not correct the mistake after a predefined period of time, this new version of the PT interrupts the user pointing out the mistake and explaining how to correct it.

Chapter IV presents a quasi-experimental study that explores the effects of the feedback provided by this new version of the PT. This study had two groups of participants: a treatment group that received feedback instructions from the PT and a control group that did not receive these instructions. During the study participants practiced an elevator pitch five times using the PT. After practicing with the PT participants gave a final pitch without its support. Results from the study show that according to machine-based measurements, the feedback of the PT helps learners to significantly improve their performance. Results also show that the feedback of the PT helps to improve self-confidence of learners, and helps learners to become better at identifying their mistakes.

Results from Chapter IV show that the interface of the PT is able to provide learners with the type of immediate feedback that helps them to improve their performance according to machine-based measurements. The objective of the second iteration from the design-based research approach is to explore whether practicing with the PT also leads to better presentations according to human audiences, and therefore supports learners in becoming better public speakers. Two main aspects were studied for this iteration:

- The assessment and feedback model of the PT: is the assessment and feedback model of the PT in agreement with the view of experts?
- Training with the PT and human assessment: do learners that practice with the PT give better presentations according to their peers?

Chapter V describes a study where expert public speakers and teachers in public speaking were interviewed regarding the nonverbal communication aspects that affect the quality of a presentation and their expert opinion on how a tool such as the PT could be used to support the development of public speaking skills. Results from this study identify a set of effective and ineffective nonverbal communication practices that affect the quality of a presentation, and discuss how the recognition of these practices could be implemented with the use of sensor-based prototypes. The interviewed experts pointed out the relevance of human tutors and explained how letting learners practice homework assignments with the PT could enhance public speaking courses. Experts also suggested changing the focus of the PT's feedback so that it supports the raise of awareness in learners instead of just correcting them.

The study described in Chapter VI explores whether practicing with the PT leads to better presentations according to human audiences. It describes a study where non-novice presenters gave a pitch in front of a human audience before and after practicing with the PT and the human audience assessed both pitches. Results show that the assessments of all pitches performed after practicing with the PT were better than the assessments from the pitches prior to the practice sessions. Participants in the study also reported that they would like to use a tool such as the PT to practice for future presentations, and acknowledged that the PT's feedback is a good complement to the feedback that peers and tutors can give.

Results from Chapter V and Chapter VI provided information on how to continue with the improvement of sensor applications designed to support the development of public speaking skills. The aim of the third iteration of the research approach is to continue with this improvement focusing on:

- Enhancing the PT with a self-reflection module.
- Exploration on how a sensor-based application such as *the Booth* can support learners with the preparation of a supportive mindset for giving presentations.
- The identification of weaknesses and educational opportunities of using the PT and *the Booth* for an oral communication course in a secondary school.

One key finding from Chapter V is that ultimately there is no right way to do a presentation, therefore providing the learner only with corrective feedback, as the PT does, might not always be desirable. Experts interviewed in Chapter V commented on how a tool such as the PT could be improved by helping learners to reflect about their performance. Chapter VII presents a formative study on a self-reflection module for the PT. Participants from the study had the chance to have two practice sessions with the newly enhanced version of the PT that includes the self-reflection module. Participants stated their appreciation for the self-reflection module, found it easy to understand, and reported that it helped them to become aware of their performance. Based on the acquired self-awareness from the first practice session, participants made a conscious effort to improve certain behaviors during the second one. Based on the acquired self-awareness from the first practice session, participants made a conscious effort to improve certain behaviors during the second one. Participants were able to maintain this conscious effort only for the first few seconds of their second practice session, therefore the study show no significant effects from the self-reflection module in the participants' performance. The most interesting result from this study is that one third of the participants, without being asked, stated the importance of rewriting the script of their pitch based on the information presented by the self-reflection module.

Public speaking is an event that can cause anxiety in speakers, and this anxiety can undermine their performance. To avoid a decrement in performance caused by anxiety, it is important to emotionally prepare for foreseeable events that can be interpreted as stressful. *The Booth* is a sensor-based application that guides the user through a set of psychological exercises designed to help people to reduce feelings of stress and anxiety, while increasing feelings of confidence and personal power. Chapter VIII presents a study exploring the effects of using the Booth in the emotional state of users. Results from the study illustrate that participants after using *the Booth* reported to have significantly more positive emotions such as happiness, joy, enthusiasm, etc. and significantly less negative emotions such as anger, stress, anxiety, etc.

The research presented in this dissertation continued with a field study (Chapter IX) conducted in a secondary school where first grade students following a five-week course on oral communication used the PT and *the Booth*. The aim this study was to identify the weaknesses and educational opportunities of these tools. Students participating on the study reported to feel motivated to use the PT in the future, and considered it as a useful learning tool. Results pointed out that the current version of the PT, as a stand alone application for novice learners is not comprehensive enough. Before letting novice learners practice with the PT, it is important to remind them about the nonverbal communication aspects to be trained. With the help of the self-reflection module of the PT, novice learners were able to identify unwanted behaviors, but did not know how to improve them. The study also showed that giving a presentation to a pair of peers is a stressful event for secondary school students, and that *the Booth* can help them to feel emotionally better while giving a presentation and more satisfied about their performance.

Chapter X starts by discussing the main findings of the conducted research. It includes findings from each particular study and some unreported findings that happened to be general throughout the conducted research and could not be pinpointed to any specific study. It concludes that sensors can be used to support a vast number of learning applications. In terms of feedback, sensor-based feedback can become overwhelming for the learner, thus needs to be carefully designed. In the case of public speaking a carefully designed sensor-based feedback can help learners to give better presentations according to machine-based performance and human audiences. Showing captured pieces of sensor-data in the form of self-reflection modules help learners to become aware of their performance. Overall, sensor-based applications for learning are well accepted by learners and can enhance current public speaking courses. This by giving learners the opportunity to practice while receiving feedback without the supervision of a human tutor, and by helping learners to emotionally prepare for presentations.

The discussion continues by presenting the limitations of the research, which include limitations regarding the scope of the research project such as constraining the research topic to the development of nonverbal communication skills for public speaking. It also discusses the limitations presented in the studies highlighting the lack of evidence regarding the medium and long term learning effects of using the PT. Finally it also reviews limitations about sensor-based learning support in general. It exposes the limited availability of sensors and points out that sensor applications for learning require a framework able to map in a meaningful way the sensor data.

By taking into account the findings and limitations previously reviewed, the chapter then suggests paths for future research regarding the use of sensors to support the development of public speaking skills and discusses how some of the findings of the conducted research, such as the proposed feedback mechanism of the PT can be generalized and used for different learning applications. Finally the author expresses his concerns regarding the purpose of education taking in consideration the current advances in technology; underlining the relevance to reflect on “how to best live” as it was already pointed out long time ago by Socrates.

Samenvatting

In dit proefschrift worden de resultaten gepresenteerd van het wetenschappelijk onderzoek dat werd uitgevoerd om het gebruik te onderzoeken van sensors die leren ondersteunen. Het onderzoek begint met het bestuderen van de huidige stand van zaken op het gebied van sensors die leren ondersteunen. Daarna wordt het onderzoek gepositioneerd binnen het Metalogue project. Op basis hiervan wordt het gebruik van sensors onderzocht die de ontwikkeling van spreken in het openbaar ondersteunen. Het onderzoek maakt gebruik van een ontwerp gebaseerde onderzoeksbenadering bestaande uit drie iteraties.

Om de huidige stand van zaken over het gebruik van sensors die leren ondersteunen vast te stellen, werd een systematisch literatuuronderzoek (Hoofdstuk II) uitgevoerd. In dit literatuuronderzoek worden 82 verschillende op sensors gebaseerde prototypen geanalyseerd op basis van hun potentiële bijdrage aan het cognitieve, affectieve en psychomotorische leerdomein. Vervolgens wordt onderzocht hoe de geselecteerde, op sensors gebaseerde prototypes, de implementatie van formatieve evaluatie kunnen ondersteunen. Het onderzoek wordt afgerond met een uitgebreide analyse van de feedback mechanismen van de prototypes.

Uit de resultaten van dit onderzoek blijkt dat sensorapplicaties ondersteuning bieden aan de drie genoemde leerdomeinen en kunnen worden gebruikt voor een breed scala aan onderwijsgebieden, hieronder wetenschap, sport en kunst. Toepassingen waarbij sensors worden gebruikt kunnen de implementatie van formatieve evaluatie ondersteunen door belangrijke aspecten ervan te ondersteunen, zoals kennis van het onderwerp, kennis van criteria en normen, houding ten opzichte van het onderwijs, expertise bij het vaststellen van evaluatieve vaardigheden, zelfbeoordeling en feedback. Bij de analyse van de prototypes kwam ook naar voren dat de op sensors gebaseerde leerondersteuning zich nog in een vroeg ontwikkelingsstadium bevindt: de leereffecten van de prototypes waren nauwelijks bestudeerd; de feedbackmechanismen van de prototypes waren vrijwel niet onderbouwd; het feedbackmechanisme van de prototypes was beperkt tot het uitzenden van een signaal en de meeste van de op sensors gebaseerde prototypes hadden geen duidelijk educatief ontwerp geïmplementeerd.

De eerste iteratie van de ontwerp gebaseerde onderzoeksbenadering begint met een formatief onderzoek (Hoofdstuk III) van de Presentatie Trainer (PT). De PT is een instrument dat is ontworpen om de ontwikkeling van basis, non-verbale communicatievaardigheden tijdens het spreken in het openbaar te ondersteunen. Het registreert, analyseert en levert real-time feedback over bepaalde aspecten van de non-verbale communicatie van de gebruiker, zoals houding, gebruik van gebaren, gebruik van pauzes en stemvolume. Dit onderzoek rapporteert over de gebruikersonderzoeken, die zijn uitgevoerd met de eerste twee versies van de PT.

De eerste versie van de PT geeft de gebruikers feedback via een dashboard dat bestaat uit feedback items die werken als semaforen en die van groen in rood veranderen wanneer er een fout van de gebruiker wordt vastgesteld. Resultaten uit de gebruikerstests van deze eerste versie van de PT tonen aan dat er veel enthousiasme onder de deelnemers bestaat om de PT voor het oefenen van toekomstige presentaties te gebruiken. De deelnemers vonden het echter moeilijk om tijdens het oefenen hun aandacht te houden bij alle feedback items. Bovendien werd geconstateerd dat de deelnemers hun gedrag niet konden aanpassen op basis van de feedback die de PT gaf.

De tweede versie van de PT werd verbeterd op basis van de bevindingen uit de eerste gebruikerstest. Bij deze tweede versie van de PT zijn er twee gebruiksopties: een oefenmodus en een freestyle-modus. De oefenmodus begeleidt de gebruikers bij een reeks verschillende oefeningen die zijn ontworpen om te helpen bij het automatiseren van bepaalde gedragingen (bijv. kort spreken en aansluitend terugkeren naar een standaard houding, harder praten, zachter praten etc.). De freestyle modus werkt vergelijkbaar met de eerste versie van de PT, maar de visuele aspecten van de dashboard interface werden verbeterd. Een verbeterd spiegelbeeld van de leerling werd toegevoegd, waarbij de verkeerde houding van de leerling werd getoond op een skeletachtige visualisatie van de leerling. In plaats van ballen die als semaforen werken, laat deze nieuwe dashboardinterface pictogrammen zien die bestaan uit twee woorden, die instructies geven over hoe de fouten kunnen worden gecorrigeerd. De gebruikerstest van deze tweede versie van de PT leverde drie belangrijke bevindingen op:

- Een oefenmodus kan helpen bij het automatiseren van bepaalde gedragingen.
- Voordat de PT gebruikt wordt, dient er een toelichting gegeven te worden over hoe er op de juiste manier gereageerd dient te worden op de feedback.
- Een dashboardinterface met feedback op meerdere aspecten tegelijkertijd is niet optimaal voor leren.

Op basis van deze bevindingen is een nieuwe versie van de PT ontwikkeld. Deze nieuwe versie analyseert het gedrag van de gebruiker en op basis van deze analyse biedt het de gebruiker maximaal één feedback instructie op één bepaald moment. Als de gebruiker een fout meerdere keren herhaalt of de fout na een vooraf bepaalde tijd niet corrigeert, onderbreekt deze nieuwe versie van de PT de gebruiker, wijst hem op de fout en legt uit hoe hij deze kan corrigeren.

In Hoofdstuk IV wordt een quasi-experimenteel onderzoek behandeld dat de effecten nagaat van de feedback die door deze nieuwe versie van de PT wordt gegeven. In dit onderzoek werden de deelnemers in twee groepen verdeeld: een interventiegroep die feedback-instructies kreeg van de PT en een controlegroep, die deze instructies niet had ontvangen. Tijdens het onderzoek oefenden deelnemers vijf keer een elevator pitch met behulp van de PT. Na het oefenen met de PT gaven deelnemers een laatste pitch zonder hulp van de PT. Resultaten uit het onderzoek tonen aan dat de feedback van de PT, volgens metingen die werden vastgelegd door een machine, de leerlingen helpt om hun prestaties significant te verbeteren. Resultaten tonen ook aan dat de feedback van de PT bijdraagt aan het verbeteren van het zelfvertrouwen van de leerlingen en de leerlingen helpt vaardiger te worden in het ontdekken van hun fouten.

Uit de resultaten van hoofdstuk IV blijkt dat de interface van de PT in staat is de leerlingen onmiddellijk het soort feedback te geven dat hen helpt om hun prestaties te verbeteren volgens metingen die werden vastgelegd door een machine. Het doel van de tweede iteratie van de ontwerp gebaseerde onderzoeksbenadering is om te onderzoeken of het oefenen met de PT ook volgens toehoorders leidt tot betere presentaties en derhalve de leerlingen ondersteunt om betere sprekers in het openbaar te worden. Voor deze iteratie werden twee belangrijke aspecten bestudeerd:

- Het beoordelings- en feedbackmodel van de PT: komt het beoordelings- en feedbackmodel van de PT overeen met de mening die deskundigen hierover hebben?
- Training met de PT en beoordeling door anderen: geven de leerlingen die met de PT oefenen, betere presentaties volgens hun medeleerlingen?

Hoofdstuk V beschrijft een onderzoek waarin ervaren sprekers en docenten ‘spreken in het openbaar’ werden geïnterviewd over non-verbale communicatieaspecten, die de kwaliteit van een presentatie beïnvloeden en hun deskundige opinie over hoe een instrument als de PT kan worden gebruikt om de ontwikkeling van deze vaardigheden voor spreken in het openbaar te ondersteunen. Uit de resultaten van dit onderzoek komen een reeks effectieve en ineffectieve non-verbale communicatiepraktijken naar voren, die de kwaliteit van een presentatie beïnvloeden en wordt besproken hoe de herkenning van deze praktijken kan worden geïmplementeerd met behulp van op sensors gebaseerde prototypes. De geïnterviewde deskundigen wezen op de relevantie van tutors en legden uit hoe met het laten oefenen van leerlingen met de PT door het maken van huiswerkopdrachten, de cursussen over spreken in het openbaar verbeterd kunnen worden. Experts stelden ook voor om de focus van de feedback van de PT te veranderen, opdat het de bewustmaking van leerlingen ondersteunt in plaats van hen alleen te corrigeren.

In het onderzoek dat wordt beschreven in hoofdstuk VI wordt onderzocht of het oefenen met de PT volgens de toehoorders leidt tot betere presentaties. Het beschrijft een onderzoek waarin presentatoren een pitch gaven in het openbaar voor en nadat ze geoefend hadden met de PT en het publiek beide pitchen had beoordeeld. Uit de resultaten blijkt dat de beoordelingen van alle pitches die zijn gehouden na het oefenen met de PT beter waren dan de beoordelingen van de pitches voorafgaand aan de oefensessies. Deelnemers aan het onderzoek hebben ook gerapporteerd dat zij graag een tool als de PT willen gebruiken om te oefenen voor toekomstige presentaties en bevestigden dat de feedback van de PT een goede aanvulling is op de feedback die medeleerlingen en docenten kunnen geven.

De resultaten van hoofdstuk V en hoofdstuk VI verschaften informatie over hoe verder te gaan met de verbetering van sensorapplicaties die zijn ontworpen om de ontwikkeling van spreekvaardigheden in het openbaar te ondersteunen. Het doel van de derde iteratie van deze onderzoeksbenadering is om deze verbetering voort te zetten met de focus op:

- Een zelfreflectiemodule toevoegen aan de PT.
- Onderzoeken hoe een op sensors gebaseerde applicatie zoals *de Booth*, leerlingen kan ondersteunen bij de mentale voorbereiding om presentaties te geven.
- Identificeren van zwakke punten en onderwijskansen om de PT en *de Booth* in te zetten bij een cursus mondelinge communicatie op een middelbare school.

Een belangrijke bevinding uit hoofdstuk V is dat er uiteindelijk geen juiste manier is om een presentatie te geven. Daarom is het wellicht niet altijd wenselijk om de leerling alleen correctieve feedback te geven, zoals de PT doet. De in hoofdstuk V geïnterviewde experts hebben aangegeven hoe een hulpmiddel zoals de PT verbeterd kan worden door leerlingen te helpen over hun prestaties te reflecteren. In Hoofdstuk VII wordt een formatief onderzoek over een zelfreflectiemodule voor de PT gepresenteerd. Deelnemers aan het onderzoek kregen de mogelijkheid om twee oefensessies te doen met de nieuwe verbeterde versie van de PT waaraan de zelfreflectiemodule was toegevoegd. Deelnemers uitten hun waardering voor de zelfreflectiemodule, vonden het makkelijk te begrijpen en meldden dat het hen hielp bij de bewustwording van hun prestaties. Op basis van het verworven zelfbewustzijn uit de eerste oefensessie, deden de deelnemers een bewuste inspanning om bepaalde gedragingen tijdens de tweede sessie te verbeteren. Op basis van het verworven zelfbewustzijn van de eerste oefensessie, hebben de deelnemers een bewuste inspanning gedaan om bepaalde houdingen tijdens de tweede sessie te verbeteren. Deelnemers konden deze bewuste inspanning alleen maar de eerste paar seconden van hun tweede oefensessie volhouden. Daarom blijkt uit het onderzoek dat er door het toevoegen van de zelfreflectiemodule geen significante effecten zijn op de prestaties van de deelnemers. Het meest interessante resultaat dat uit dit onderzoek naar voren kwam, is dat een derde van de deelnemers, zonder dat ze gevraagd werden, het belang aangaven van het herschrijven van het script van hun pitch op basis van de informatie die door de zelfreflectiemodule werd aangeleverd.

Spreken in het openbaar is een gebeurtenis die kan zorgen voor angst bij sprekers en deze angst kan hun prestaties ondermijnen. Om te vermijden, dat deze angst de prestatie beïnvloedt, is het belangrijk om emotioneel voorbereid te zijn op gebeurtenissen die voorspelbaar als stressvol kunnen worden ervaren. *De Booth* is een op sensors gebaseerde applicatie die de gebruiker begeleidt bij een reeks psychologische oefeningen die zijn ontworpen om mensen te helpen om gevoelens van stress en angst te verminderen terwijl de gevoelens van vertrouwen en persoonlijke kracht toenemen. In Hoofdstuk VIII wordt een onderzoek gepresenteerd, waarbij de effecten op de emotionele toestand van de gebruikers wordt onderzocht door *de Booth* te gebruiken. Resultaten uit het onderzoek geven aan dat deelnemers na het gebruik van *de Booth* aanzienlijk meer positieve emoties hebben, zoals geluk, vreugde, enthousiasme, enz. en aanzienlijk minder negatieve emoties zoals woede, stress, angst, enz.

Hoofdstuk IX beschrijft een veldonderzoek in een middelbare school waar leerlingen uit de eerste klas een cursus van vijf weken volgden over mondelinge communicatie met gebruikmaking van de PT en *de Booth*. Het doel van dit onderzoek was om de zwakke punten en onderwijskansen van deze instrumenten te identificeren. Studenten die deelnamen aan het onderzoek meldden dat ze ertoe aangespoord waren om de PT in de toekomst te gebruiken en beschouwden het als een nuttig leermiddel. Resultaten wijzen erop dat de huidige versie van de PT, als een alleenstaande toepassing voor beginnende leerlingen, niet volledig genoeg is. Vooraleer de beginnende leerlingen met de PT te laten oefenen, is het belangrijk om hen te wijzen op de niet-verbale communicatie-aspecten, die moeten worden geoefend. Met behulp van de zelfreflectiemodule van de PT waren de beginnende leerlingen in staat om ongewenste gedragingen te identificeren, maar wisten niet hoe ze die konden verbeteren. Uit het onderzoek bleek ook dat het geven van een presentatie aan andere leerlingen een stressvolle gebeurtenis is voor leerlingen van een middelbare school en dat *de Booth* hen kan helpen om zich emotioneel beter te voelen tijdens de presentatie en meer tevreden te zijn over de prestaties.

In Hoofdstuk X worden de belangrijkste bevindingen van de uitgevoerde onderzoeken besproken. Het bevat bevindingen van elke specifieke studie en enkele niet gerapporteerde bevindingen die doorgaans van algemene aard waren en niet naar een bepaald onderzoek kunnen worden herleid. De conclusie is dat sensors kunnen worden gebruikt om een groot aantal leerapplicaties te ondersteunen. In termen van feedback kan op sensors gebaseerde feedback overweldigend worden voor de leerling, en moet daarom zorgvuldig worden ontworpen. Bij spreken in het openbaar kan een zorgvuldig ontworpen op sensors gebaseerde feedback de leerlingen helpen om betere presentaties te geven volgens machine-gebaseerde criteria en volgens een menselijk publiek. Het tonen van door sensors vastgelegde data in de vorm van zelfreflectiemodules helpt de leerlingen zich bewust te worden van hun prestaties. Over het geheel genomen worden op sensors gebaseerde applicaties voor leren door de leerlingen goed geaccepteerd en kunnen ze de huidige cursussen spreken in het openbaar verbeteren. Dit gebeurt door de leerlingen de mogelijkheid te geven om te oefenen terwijl ze feedback krijgen zonder het toezicht van een tutor, en door leerlingen te helpen bij de emotionele voorbereiding op presentaties.

De discussie wordt vervolgd door de beperkingen van het onderzoek aan te geven, waaronder beperkingen met betrekking tot de reikwijdte van het onderzoeksproject dat wil zeggen het beperken van het onderzoeksonderwerp tot de ontwikkeling van nonverbale communicatievaardigheden voor spreken in het openbaar. Ook komen de beperkingen in het onderzoek aan bod met betrekking tot het gebrek aan bewijsmateriaal ten aanzien van de leereffecten op middellange en lange termijn bij het gebruik van de PT. Tenslotte gaat het ook om beperkingen over op sensors gebaseerde leerondersteuning in het algemeen. Het toont de beperkte beschikbaarheid van sensors en wijst erop dat sensorapplicaties voor leren een raamwerk nodig hebben om de sensorgegevens op een zinvolle manier te kunnen interpreteren toepassen.

Rekening houdende met de bevindingen en beperkingen die eerder zijn beschreven worden in het hoofdstuk vervolgens paden voor toekomstig onderzoek voorgesteld naar het gebruik van sensors ter ondersteuning van de ontwikkeling van spreekvaardigheden in het openbaar en wordt besproken hoe sommige van de bevindingen van het uitgevoerde onderzoek, zoals het voorgestelde terugkoppelingsmechanisme van de PT, kunnen worden gegeneraliseerd en worden gebruikt voor verschillende leertoepassingen. Tenslotte sluit de auteur af met het uitspreken van zijn bezorgdheid over het doel van het onderwijs vanuit het perspectief van de huidige vooruitgang in de technologie; de relevantie benadrukkend van het denken over 'op welke manier kun je het beste leven' zoals al heel lang geleden door Socrates werd opgemerkt.

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